EXHIBIT A

Intended for
Riley, Safer, Holmes, & Cancila LLP

Document type
Expert Report

Date
March 2020

Project Number
1690015648-001

DAUGHERTY EXPERT OPINION

PAMELA BUTLER, ET AL. VS. MALLINCKRODT, INC., ET AL.

UNITED STATES DISTRICT COURT FOR THE EASTERN DISTRICT OF MISSOURI CASES: 4:18 CV 01701, 4:18 CV 01702, 4:18 CV 01703, 4:18 CV 01704

Douglas Daugherty, PhD, PE, CIH

CONTENTS

EXHIBITS

1. QUALIFICATIONS

I am a California registered professional (chemical) engineer (PE), a certified industrial hygienist (CIH) with the American Board of Industrial Hygiene, and the Regional Chief-Operating-Officer for Ramboll's Environment & Health, West US operations. Ramboll is a scientific consulting firm that specializes in environmental matters, with offices throughout the United States (US) and overseas. Prior to joining Ramboll, I received a masters and doctorate in Chemical Engineering from Princeton University and a Bachelor of Science in Chemical Engineering from Johns Hopkins University.

I have performed air-related research consulting for over 20 years. I am an author of more than 30 scientific papers, including some that are peer reviewed, presentations, and over a hundred technical reports in the fields of air quality, exposure assessment, risk assessment, and the evaluation of chemical fate and transport in the environment. One of my primary areas of expertise is the evaluation of air-related environmental impacts of emissions from industrial and other sources, such as those at issue in this litigation. This includes calculations regarding the nature and quantity of airborne emissions from various sources and air dispersion modeling to estimate concentrations of emitted material in ambient air.

I have broad experience advising and assisting facilities in a wide variety of industries with air compliance programs at both the federal and state level. I have developed Emission Inventory Plans and Reports, a process that involves the estimation of criteria pollutant and air toxics emissions from process facilities, fugitive dust sources, and mobile source activities at a given site. I have developed and executed long-term monitoring programs that have included air contaminants such as metals, diesel, particulate matter, and a variety of chemicals and radionuclides (e.g., Ra-226, Ra-228, Th-232, U-238). I have also applied these methods to determine the feasibility of installing control measures and to evaluate the potential impact of proposed physical and/or operational changes at a site for both process stack and fugitive emissions sources. I have considerable experience with ambient air sampling, including selection of monitoring locations and equipment, sampling procedures and field Quality Assurance/Quality Control (QA/QC), laboratory analysis and laboratory QA/QC, data quality objectives, and data reporting.

I have extensive expertise in the use and application of air dispersion models, including the United States Environmental Protection Agency's (USEPA) recommended model, AERMOD, since its introduction. For example, I conducted American Meteorological Society/USEPA Regulatory Model (AERMOD) modeling assessments of emissions from various industrial sources for permitting purposes as well as modeling assessments of eight rail yards in California, which were reviewed and approved by the California Air Resources Board (CARB), and an assessment of all mobile source operations at the Ports of Los Angeles and Long Beach; this work pioneered the application of AERMOD in

California.[1,2,3,4,5,6] I have conducted numerous air dispersion modeling assessments for a variety of industrial, mining, and transportation facilities. These air dispersion modeling assessments have included both stack and fugitive emission sources, which released a variety of contaminants, such as metals, diesel, particulate matter, and a variety of chemicals and radionuclides (e.g., Ra-226, Ra-228, Th-232, U-238). I also have considerable experience working with both local and federal air permitting authorities on matters involving local and federal air quality regulations, some of which require emission inventory development and/or air dispersion modeling. In addition to my direct project experience, I have shared my expertise regarding various aspects of AERMOD through teaching courses, publishing scientific articles, and presenting to my peers at professional conferences.

Given my experience in air quality, exposure assessment, and environmental, health and safety issues, I was selected by the National Research Council (NRC) to contribute to the review of environmental, health, and safety sections of the National Nanotechnology Initiative's report, A Matter of Size: Triennial Review of the National Nanotechnology Initiative. I have presented expert testimony in cases in both federal and state courts on matters related to air quality, exposure assessment, and risk assessment.

Attached, as Exhibit A, is a copy of my curriculum vitae, which provides a detailed description of my academic and professional experience and qualifications and a list of my scientific papers and presentations. Exhibit B contains a list of my expert testimony in the past five years.

Ramboll is paid at the hourly rate of $355 for my time, including for deposition and trial testimony.

[1] Bentley, L., T. Bowie, G. Hoch, and D. Daugherty. 2007. Specification of Surface Parameter Values for the AERMET Preprocessor for Geographical Areas with Atypical Seasonal Patterns. 2007 Annual AWMA Meeting. Pittsburgh, PA. June.

[2] Daugherty, D. D., W. Li, K. Mertz, and S. Hayes. 2003. The Importance of Surface Roughness Selection in AERMOD Modeling for Shoreline Sources. Paper 81161. 2003 Annual Meeting, Air & Waste Management Association, San Diego, CA. June.

[3] Hoch, G., C. Barney, and D. D. Daugherty. 2006. A Case Study in Meteorological Monitoring: Evaluation of Potential Impacts on Data Quality Using Non-Traditional Data Analysis Techniques. Paper 495. 2006 Annual Meeting, Air & Waste Management Association, New Orleans, LA. June.

[4] Mukai, C., T. Bowie, G. Hoch, and D. Daugherty. 2007. Evaluation of Urban Boundary Layer Parameters in AERMOD or Poorly-Defined Urban Areas. 2007 Annual AWMA Meeting. Pittsburgh, PA. June.

[5] Payer, B. W., S. Lee, G. M. Hoch, and D. D. Daugherty. 2008a. Assessing the Uncertainty from Source Selection and Representation for Mobile Emission Source Activities in Air Dispersion Modeling Assessment of Goods Movement Facilities. Poster presented at Transportation Research Board of the National Academies Data for Goods Movement Impacts on Air Quality Conference, Irvine. March.

[6] Payer, B. W., S. Lee, G. M. Hoch, and D. D. Daugherty. 2008b. Evaluation of Source Selection and Representation for Mobile Emission Source Activities on Air Dispersion Modeling Setup Time, Run Time, and Modeling Results Using AERMOD. Presented at 2008 Annual Meeting, Air & Waste Management Association, Portland, Oregon. June.

2. SCOPE OF ENGAGEMENT

Ramboll has been retained by counsel for Cotter Corporation (N.S.L.) in the matters of Pamela Butler, Kenneth Koterba, Anthony Hines, and Emery David Walick, III ("Plaintiffs") v. Mallinckrodt Inc. ("Mallinckrodt") and Cotter Corporation (N.S.L.) ("Cotter"). In the above-referenced matters, the Plaintiffs claim that Mallinckrodt and Cotter released radioactive substances from two sites in St. Louis County, Missouri: (1) the St. Louis Airport Site ("SLAPS") and (2) the Hazelwood Interim Storage Site, located at 9200 Latty Avenue in Hazelwood (abbreviated as HISS by other experts in this case; herein referred to as the "Latty Avenue site" or the "site"). More specifically, Plaintiffs claim that

> Mallinckrodt's acts and omissions between approximately 1942 and 1957 caused the release of hazardous, toxic, and radioactive substances into the environment along haul routes and in north St. Louis County, Missouri, thereby contaminating the air, soil, surface water, and ground water along the haul routes and in the area surrounding SLAPS and Coldwater Creek.[7]

Additionally, Plaintiffs claim that

> Cotter's acts and omissions between approximately 1969 and 1973 caused the release of hazardous, toxic, and radioactive substances into the environment in north St. Louis County, Missouri, thereby contaminating the air, soil, surface water, and ground water in the area.[8]

My report focuses on claims related to the Latty Avenue site during the five-year period between December 30, 1969 and November 13, 1974 (1970-1974 for ease of reference) when Cotter held a radioactive materials license for the Latty Avenue site issued by the Atomic Energy Commission (AEC). I recognize that other experts in this case have evaluated other sites and time periods and I reserve the right to amend this report with additional analyses that address these sites and time periods, if desired.

Given my background and expertise in air dispersion modeling (including emission estimation methodology, which is used in estimation of airborne concentrations), I was asked to perform an independent evaluation of Plaintiffs' experts' conclusions related to the airborne release and transport of radiological materials from the Latty Avenue site. In particular, I have evaluated Dr. Wells' calculation of fenceline radionuclide and radon concentrations at the Latty Avenue site and his comparison of these concentrations to historical effluent limits. Dr. Wells' methodology and conclusions are described in his March 31, 2019 Expert Report; August 1, 2019 Supplemental Expert Report; and October 17, 2019 deposition testimony.

[7] United States District Court, Eastern District of Missouri, Eastern Division. Complaint, Pamela Butler v. Mallinckrodt, Inc., et al. Case No. 4:18-CV-01701. 2018. Oct. 5; United States District Court, Eastern District of Missouri, Eastern Division. Complaint, Kenneth Koterba v. Mallinckrodt, Inc., et al. Case No. 4:18-CV-01702. 2018. Oct. 5; United States District Court, Eastern District of Missouri, Eastern Division. Complaint, Anthony Hines v. Mallinckrodt, Inc., et al. Case No. 4:18-CV-01703. 2018. Oct. 5; United States District Court, Eastern District of Missouri, Eastern Division. Complaint, Emery David Walick v. Mallinckrodt, Inc., et al. Case No. 4:18-CV-01704. 2018. Oct. 5.

[8] Ibid.

As discussed in further detail in Section 3.3 and throughout my report, Dr. Wells' airborne concentration analyses are reliant on one primary document: an April 27, 2018 Risk Assessment Corporation (RAC) report, titled *Reconstruction of Plaintiff Doses Associated with Residues Stored at the St. Louis Airport Storage Site and the Hazelwood Interim Storage Site and Critique of Opinions by Dr. Cheremisinoff, Ms. Sears and Dr. Clark* ("RAC report"). This report and its underlying analyses represent the opinions of John E. Till, Ph.D. and others on behalf of Mallinckrodt, in a previous litigation. While Dr. Wells' reliance on RAC is both inappropriate and scientifically problematic, especially given Dr. Wells' failure to understand and correctly apply information in the RAC report (as discussed in my opinions), counsel has requested that I evaluate Dr. Wells' calculations and underlying assumptions. This should not, however, be misconstrued as an endorsement of RAC's methodology or conclusions; I reserve the right to amend this report with further assessment of RAC's methodology, if desired.

In developing my opinions, I have reviewed the reports and analyses of several other experts in this matter, including Mr. Robert M. Zoch, Jr., P.E. and Mr. Jason Miller. Mr. Zoch provides opinions related to historical site operations, emissions, and the chemical and physical properties of the process residues stored and handled at the Latty Avenue site. Based on my professional judgement and review of the underlying case and available scientific documents, I have elected to rely on Mr. Zoch's analysis of the process residues. Mr. Miller provides opinions on Dr. Wells' and other Plaintiffs' experts' claims in this matter as well as the effluent limits in 10 CFR §20.106, which are also at issue in this matter.

This report contains my opinions, provided to a reasonable degree of scientific certainty. The report is based on my education, expertise, and the documents and case materials I reviewed in preparing this report. The specific documents and case materials that I cite in this report are detailed in the footnotes and References section as well as in supporting tables, figures, and exhibits. A listing of other documents and case materials reviewed is included as Exhibit C. I reserve the right to supplement this report and my opinions as new information becomes available.

3. BACKGROUND

3.1 Site Setting and Historical Drying Operations

In the 1940s, Mallinckrodt began uranium purification operations at its plant in Downtown St. Louis ("SLDS") under a U.S. Army Manhattan Engineer District ("MED") contract.[9] In 1946, MED began storing residues from these operations at a site adjacent to the St. Louis Municipal Airport; AEC continued this practice from 1947 until 1953, when it transferred operational control of the site to Mallinckrodt (this site is herein referred to as the St. Louis Airport Site or "SLAPS").[10,11] Mallinckrodt continued to use SLAPS as an active residue storage facility until 1957 when the company transferred production to a new Weldon Spring facility under AEC contract.[12] Railroad loading support and access were added to the site in 1959 so that residues could be shipped to other locations.[13]

In 1966, Continental Mining & Milling Co. ("Continental") purchased the remaining SLAPS residues with the intent of processing these materials.[14] Between May and December of 1966,[15,16] SLAPS residues, including Congo and Colorado raffinate cakes ("AM-7" and "AM-10", respectively), leached and unleached barium sulfate ("LBSR" or "leached AJ-4" and "UBSR" or "unleached AJ-4", respectively), and C-liner slag ("CLS") were trucked to the Latty Avenue site.[17] The different types of materials were stored in separate piles at the Latty Avenue site and no additional activities related to these process resides were conducted during Continental's operations.

In December of 1966, Commercial Discount Corp. ("CDC") took over operation of the Latty Avenue site after the foreclosure of Continental.[18] CDC negotiated a purchase agreement with Cotter Corporation (N.S.L.) ("Cotter") in June 1967. Under this agreement, CDC was responsible for shipping residues stored at the Latty Avenue site to Cotter's plant in Cañon City, Colorado, at which point Cotter accepted the residues and attempted to recover uranium, copper, nickel, and cobalt from them.[19,20] CDC began shipping wet materials to Cañon City in September of 1967 and continued this practice through January of 1968.[21] On March 25, 1968, CDC began drying the Congo and Colorado

[9] MLCT_0000152155-78

[10] Buck, Alice. 1983. The Atomic Energy Commission, U.S. Department of Energy Office of History and Heritage Resources. July.

[11] MLCT 0000143086

[12] Harrington, C.D. and A.E. Ruehle. 1959. Uranium Production Technology. D. Van Nostrand Company, Inc. Princeton, NJ.

[13] Oak Ridge Associated Universities (ORAU), Dade Moeller, and MJW Technical Services ("ORAU Team"). 2010. Basis for Development of an Exposure Matrix for the Mallinckrodt Chemical Company St. Louis Downtown Site and the St. Louis Airport Site, St. Louis, Missouri ("Dose Reconstruction Project for NIOSH"). November 22. p. 51

[14] MLCT_TParty_0000084-87

[15] COTTER00009696

[16] MLCT_Tparty_0000102

[17] ORAU 2010, p. 51

[18] COTTER00006041

[19] Ibid.

[20] COTTER00003142-3153

[21] COTTER00000915, COTTER00002760-64

raffinates (AM-7 and AM-10, respectively) and shipping these dried residues to Cañon City.[22] The drying operation continued through November 1968. In total, CDC dried and shipped 24,157 dry tons of Congo raffinate (AM-7) and 11,576 dry tons of Colorado raffinate (AM-10) to Cañon City.[23]

On December 30, 1969, Cotter purchased the remaining residues at the Latty Avenue site as well as the associated drying and material handling equipment.[24] Cotter then contracted B&K Construction Company, Inc. ("B&K") to dry and ship the remaining raffinate residue to the Cañon City plant. The contract stipulated an 8 hour per day, 5 day per week work schedule.[25] In total, B&K/Cotter dried and shipped 18,745 dry tons of Congo raffinate (AM-7) to Cañon City between August 13, 1970 and February 10, 1971. B&K/Cotter dried the raffinate using Barber-Greene equipment consisting of a "natural gas fired Model 838 dryer, a Model 858 multiclone dust collector, and a Model CN70 wet scrubber utilizing a recirculating water system."[26] The remaining wet Congo raffinate (AM-7) was shipped by rail to Cañon City between April and June of 1971.[27] No Colorado raffinate (AM-10) was dried or shipped between July 1971 and June 1973, based on available documents.

By 1973, only Colorado raffinate (AM-10) and "leached AJ-4" residues remained at the Latty Avenue site. Cotter contracted B&K to execute the removal of these residues, which occurred between July and October of 1973.[28] The remaining wet AM-10 was shipped to Cañon City.[29] The leached AJ-4 was spread over a large, open area at the site and mixed with topsoil before being trucked to the West Lake Landfill.[30] Cotter thereafter applied for the termination of its AEC source material license for the Latty Avenue site, which was granted on November 13, 1974.[31]

In summary, during the Cotter (B&K) operational period (1970-1974), activities involving process residues included drying and shipping AM-7, and the final shipment of wet AM-7, AM-10, and AJ-4 (LBSR).

3.2 Materials of Interest

As described in the previous section and discussed in detail in Mr. Zoch's expert report,[32] five residue materials were stored at the Latty Avenue site:

- Pitchblende raffinate cake (AM-7): pitchblende ore raffinate residue, generated from precipitation of the acidic aqueous stream from an extraction process step in the processing of African pitchblende ore; therefore, also referred to as Congo raffinate;

[22] COTTER00003309, 3374, 3424, 3421, 3413, 3407, 3360, 3357; see also COTTER00002645-54

[23] COTTER00003436, 3357, 3360, 3362, 3365, 3368, 3371, 3374, 3377

[24] COTTER00005485-98, COTTER00005489, COTTER00005510-5518, COTTER00004840

[25] COTTER00005524-5530

[26] COTTER00002651, 4257, 4263, 4269, 4275, 4278, 4568, 4571

[27] COTTER00004561, COTTER00004559, COTTER00004557

[28] COTTER00001274-1282

[29] COTTER00001818

[30] COTTER00001818-9

[31] COTTER00006248-6249

[32] Zoch, R. 2020. Expert Report of Robert M. Zoch, Jr., PE in the Matter of Pamela Butler, et al. v. Mallinckrodt LLC and Cotter Corporation (N.S.L.). March.

- Colorado concentrate raffinate cake (AM-10): filtered solids from uranium-extracted raffinate treated with hydrated lime slurry as part of the dual-cycle extraction process for domestic uranium concentrates;
- Leached barium sulfate residue cakes (LBSR or leached AJ-4): process residue from the removal of sulfate complexes which formed in the radium/lead precipitation step using a slurry of barium carbonate that was further processed, including a two-stage sodium carbonate leach;
- Unleached barium sulfate residue cakes (UBSR or unleached AJ-4): Process residue from the removal of sulfate complexes which formed in the radium/lead precipitation step using a slurry of barium carbonate that was not processed by the sodium carbonate leach; and
- C-liner slag (CLS): crushed dolomite refractory containing less than 2% uranium.

As described in the background section and shown in Figure 3-1, only three materials (AM-7, AM-10, and leached AJ-4) were present at the Latty Avenue site during Cotter's (B&K) operational period (1970 to 1974). Additionally, AM-7 was the only material that Cotter (B&K) dried at the site prior to off-site shipment.

3.3 Dr. Wells' Evaluation of Airborne Releases and Fenceline Concentrations at the Latty Avenue Site

According to his initial expert report, Dr. Wells was

> *…retained by Humphrey, Farrington & McClain on behalf of certain plaintiffs in this case to provide scientific input and expert opinions concerning the nature and extent of contamination on and around the St. Louis Airport Storage Site (SLAPS), the Hazelwood Interim Storage Site (HISS; also known as the Latty Avenue Site) and properties in the vicinity of these sites, including Coldwater Creek: all in Missouri.*[33]

In particular, Dr. Wells was asked to address a Case Management Order, which in his purview

> *…requires plaintiffs to determine the concentrations of effluent discharges at the boundary of the SLAPS and Latty Avenue sites allegedly attributable to Mallinckrodt's and/or Cotter's operations and whether such concentrations exceed the effluent limitations found in applicable federal regulations: 10 CFR §20.106(a), Appendix B.*[34]

In order to calculate airborne concentrations to compare to the effluent limits in 10 CFR §20.106, Dr. Wells relies on emission calculations and modeling conducted by another expert in a prior litigation. For example, Dr. Wells adopts the particulate matter emission rate that Dr. Till et al. of RAC previously developed for AM-7 and AM-10 drying operations at the Latty Avenue site. Dr. Wells then calculates total radionuclide emissions from RAC's emission rates for each of the six quarters between 1968 and 1971 when CDC (1968) and Cotter (1970-1971) operated the dryer. As the effluent limits in 10 CFR §20.106 apply to off-site concentrations (in "unrestricted areas"), rather than emission rates, Dr. Wells attempts to "convert" these radionuclide emission rates "to concentrations by dividing by the

[33] Wells, J. 2019a. Expert Report of James T. Wells, PhD, PG in the matter of McClurg, et al. v. Mallinckrodt, Inc., et al. March 31. p. 1

[34] Id, p. 12

total amount of air passing across the site each quarter, incorporating the conservative assumption of thorough mixing of airborne particulates with air passing across the entire site."[35]

Although Dr. Wells uses a different methodology to evaluate radon releases from the Latty Avenue site, he relies on the same RAC report for the mathematical equation, radon release rate, and "dispersion factors" that form the basis of his calculation. Briefly, RAC used air dispersion modeling to relate airborne concentrations (χ) measured at the perimeter of the Latty Avenue site during remedial activities in 1998-2011 to emissions during these activities (Q). Dr. Wells extracts the dispersion factor ($DF=\chi/Q$) that RAC developed during this analysis and uses it to calculate fenceline radon concentrations during site operations, using a separate radon release rate that RAC developed for the primary emission source at SLAPS (not Latty Avenue) in the 1940s.

Dr. Wells compares his calculated radionuclide and radon concentrations to the effluent limits in 10 CFR §20.106. Although Appendix B contains separate limits for soluble and insoluble material, Dr. Wells uses only the lower soluble limits and opines that "effluent limits for air were exceeded at both SLAPS and Latty Avenue"[36] without consideration of the solubility of the material. Specifically, Dr. Wells concludes that calculated fenceline concentrations of thorium-230 (Th-230) exceeded the soluble effluent limit during all quarters with active residue drying operations (i.e., Q2-Q4 of 1968, Q3-Q4 of 1970, and Q1 of 1971) and that Proactinium-231 (Pa-231) concentrations exceeded the soluble effluent limit during Q2 and Q3 of 1968 and Q4 of 1970.[37] Dr. Wells also makes the general conclusion that fenceline radon concentrations at Latty Avenue exceeded the effluent limit during "the period of time that the waste material was stored onsite."[38]

As discussed in further detail in the following sections, the methodology that Dr. Wells uses to support his conclusions is scientifically unreliable. He adopts several key assumptions from the RAC report without adequate validation, and ignores other information contained in this same report that would be relevant to any analysis of airborne concentrations for comparison to effluent limits. Although Dr. Wells claims to be an expert in "fate and transport," the methodology he uses to evaluate the atmospheric transport of emissions to the Latty Avenue fenceline for comparison to airborne concentration limits is not generally accepted in the relevant scientific community. Finally, he makes errors and omissions in implementing the methodology he describes in his report, which further undermine the validity of his conclusions. As a result, his conclusion that air concentrations at the Latty Avenue fenceline historically exceeded applicable effluent limits is without scientific basis and is unreliable.

[35] Id, p. 17

[36] Id, p. 12

[37] Dr. Wells' calculated Pa-231 concentration for Q4 of 1970 exceeds the soluble limit for this radionuclide, although Dr. Wells does not highlight this quarter in Table 3 of his report (Id, Table 3).

[38] Wells, J. 2019a, p. 14-15

4. OPINION 1: DR. WELLS' ANALYSIS OF FENCELINE RADIONUCLIDE CONCENTRATIONS AT THE LATTY AVENUE SITE FOR COMPARISON TO HISTORICAL REGULATORY EFFLUENT LIMITS DOES NOT FOLLOW A SCIENTIFICALLY VALID METHODOLOGY AND CONTAINS SEVERAL ERRORS, WHICH TOGETHER SUBSTANTIALLY OVERSTATE AIRBORNE CONCENTRATIONS AND MAKE HIS ANALYSIS UNRELIABLE.

To evaluate fenceline radionuclide concentrations at the Latty Avenue site, Dr. Wells attempts to "convert" another consultant's emission estimates from dryer operations at Latty Avenue "to concentrations by dividing by the total amount of air passing across the site each quarter."[39] Despite Dr. Wells' assertion, it is not possible to simply convert an emission rate to a concentration without considering the complex physical processes that drive pollutant transport and dispersion in the atmosphere. In contrast, air dispersion modeling professionals use accepted and peer-reviewed models, designed to calculate ambient air concentrations due to specific emission sources. Moreover, there are established procedures for conducting this type of air dispersion modeling analysis, particularly for regulatory applications where calculated concentrations are to be compared to a regulatory limit, as Dr. Wells has attempted in this matter, but which he has ignored. Dr. Wells has not applied an air dispersion model or followed a reliable modeling methodology, and his estimates of fenceline radionuclide concentrations at the Latty Avenue site are both scientifically unsound and substantially inflated.

4.1 Introduction to Air Dispersion Modeling

Air dispersion models are mathematical models that regulators and trained air dispersion modeling professionals use to evaluate air concentrations due to specific emission sources. These models are routinely used for regulatory applications, such as the preparation of air permits, State Implementation Plans (SIPs), and air quality assessments required under the Clean Air Act (CAA) and other state and federal regulations. Many of these applications involve the comparison of modeled fenceline and off-site concentrations to regulatory standards or guidelines, such as Significant Impact Levels (SILs) or National Ambient Air Quality Standards (NAAQS). USEPA provides air dispersion modeling guidance in Appendix W to 40 CFR Part 51 ("Appendix W"). Appendix W specifies USEPA's preferred air dispersion models and describes the proper regulatory application of these models.[40]

As a time- and cost-saving measure, USEPA allows for the use of screening techniques to quickly determine if off-site impacts are insignificant and a more detailed modeling analysis is unnecessary.

4.2.1 Screening Models and Techniques

a. Where a preliminary or conservative estimate is desired, point source screening

[39] Wells, J. 2019a, p. 17

[40] USEPA. 2017. 40 CFR Part 51, Appendix W – Guideline on Air Quality Models. January 17.

> *techniques are an acceptable approach to air quality analyses.*
> *b. As discussed in paragraph 2.2(a), screening models or techniques are designed to provide a conservative estimate of concentrations.*[41]

Screening models tend to be easy to apply and require only limited site-specific information. In turn, these models provide conservative (i.e., biased high) concentration estimates, which allow regulators and air quality modeling professionals to evaluate whether off-site concentrations are insignificant or below regulatory limits. Failure to demonstrate this in a screening-level analysis does not demonstrate that actual off-site concentrations would exceed regulatory limits, only that a more refined modeling analysis may be warranted. A more refined modeling analysis may incorporate additional site-specific information and/or utilize a more sophisticated model, designed to provide more reasonable concentration estimates. A similar 'tiered' approach may also be used in air dispersion modeling analyses conducted for the purpose of inhalation exposure assessment, where higher tiered analyses progressively incorporate more detailed site-specific information and use more refined modeling techniques (e.g., screening-level v. refined models).[42,43,44]

Numerous screening (simple inputs) and refined (more extensive inputs) air dispersion models are publicly available for use by air dispersion modeling professionals. One example typically used for regulatory assessments involving estimation of airborne concentrations is USEPA's AERMOD and its screening version, AERSCREEN. Both models have been scientifically peer reviewed, tested, and approved for various regulatory applications, including the assessment of calculated boundary (fenceline) and off-site air concentrations for comparison to regulatory limits/thresholds and regulatory exposure assessment.[45]

AERMOD is a steady-state, Gaussian plume model that employs "state-of-practice parameterizations for characterizing the meteorological influences and dispersion."[46] AERMOD has been extensively tested using field studies that cover a range of emission and dispersion scenarios (e.g., tall stacks and low-level sources, flat and complex terrain, stacks subject to building downwash) and has consistently shown "good performance."[47] Inputs to AERMOD include:

[41] Ibid

[42] NRC. 1994. Science and Judgment in Risk Assessment. National Academy Press, Washington DC.

[43] USEPA. 2004a. Air Toxics Risk Assessment Reference Library Volume 1 Technical Resource Manual. EPA-453-K-04-001A. Available online at: https://www.epa.gov/sites/production/files/2013-08/documents/volume_1_reflibrary.pdf

[44] USEPA. 2004b. Air Toxics Risk Assessment Reference Library. Volume 2. Facility-Specific Assessment. Office of Air Quality Planning and Standards. EPA-453-K-04-001B. April. Available online at: https://www.epa.gov/sites/production/files/2013-08/documents/volume_2_facilityassess.pdf

[45] USEPA has developed other Gaussian plume dispersion models for various purposes including CAP-88, which is utilized to evaluate dose and risk from radionuclide emissions. As Dr. Wells' opinion is based on airborne concentrations (not dose or risk) estimates for his comparison to effluent standards, this report focuses on AERMOD and AERSCREEN as the more typical plume dispersion models employed to evaluate airborne concentrations against regulatory standards.

[46] USEPA 2017

[47] Ibid

- Emission source type, which describes, for example, whether a release occurs from a stack or a more diffuse emission source (e.g., storage pile);
- Emission source parameters, such as stack location, stack height, stack diameter, and stack gas exit velocity and temperature;
- Building dimensions for the evaluation of building downwash;
- Representative meteorological data, including surface wind speeds, wind directions, ambient temperatures, and cloud cover;
- Terrain and land use data; and
- The location of specific "receptors" where pollutant concentrations are calculated.

AERSCREEN is USEPA's recommended screening model and applies AERMOD's algorithms in "screening mode." While AERSCREEN requires fewer site-specific inputs, it is still a USEPA-approved dispersion model. Inputs to AERSCREEN include:

- Emission source type (e.g., point/stack, area);
- Emission source parameters (e.g., stack location, stack height, stack diameter, stack gas exit velocity and temperature);
- Building dimensions, if building downwash is to be evaluated; and
- Distance to the nearest off-site receptor.

AERSCREEN outputs represent worst-case concentrations at varying distances from the release point, for averaging periods ranging from one hour to one year.[48] USEPA studies have shown that AERSCREEN produces higher concentration estimates than AERMOD across a wide range of applications.[49]

Both AERMOD and AERSCREEN are publicly available for download through USEPA's online Support Center for Regulatory Atmospheric Modeling (SCRAM). SCRAM also houses users guides, model support documentation, installation guides, and sample input/output files to help air dispersion modeling professionals understand and use these models.[50]

[48] AERSCREEN calculates worst-case 1-hr concentrations and uses scaling ratios to provide worst-case 3-hr, 8-hr, 24-hr, and annual average concentrations (USEPA. 2016. AERSCREEN User's Guide. EPA-454/B-16-004).

[49] Thurman, J. 2008. AERSCREEN: Status and Update. 9th Modeling Conference. USEPA Support Center for Regulatory Atmospheric Modeling ("SCRAM"). October 9. Available online at: https://www3.epa.gov/scram001/9thmodconf/aerscreen_9thmc_1009.pdf

[50] USEPA SCRAM. Air Quality Dispersion Modeling – Preferred and Recommended Models. Available online at https://www.epa.gov/scram/air-quality-dispersion-modeling-preferred-and-recommended-models. Last Accessed December 1, 2019.

4.2 Dr. Wells' Box Model Is Not an Accepted Practice in the Air Quality Modeling Field and Fails to Accurately Represent Historical Conditions at the Latty Avenue Site and the Physical Processes that Drive Pollutant Transport in the Atmosphere

Although Dr. Wells had ready access to the scientifically developed and tested air dispersion models that professionals in the field routinely apply, he chose not to apply any of these models.

A. I performed some calculations, but I don't think I would call it modeling.[51]

Instead, he attempted to "convert" radionuclide emission rates to air concentrations by assuming the Latty Avenue site was a 206 meter (m) by 206 m by 10 m tall, well-mixed box. This type of simplified "box model" is not typically used to evaluate air concentrations in the outdoor environment, as it does not consider the physical characteristics of an emissions source (e.g., stack height, temperature, velocity) or the meteorological phenomena that drive pollutant dispersion in the atmosphere (see Figure 4-1 below). Instead, box models are typically used to estimate concentrations in enclosed and relatively well-mixed environments, such as workrooms, for the purpose of estimating occupational exposures (e.g., Figure 4-2 below).[52] In addition to failing to apply an accepted modeling methodology, Dr. Wells also fails to implement his box model correctly to account for historical operations at the Latty Avenue site. As a result, the fenceline radionuclide concentrations that Dr. Wells calculates are inflated, without scientific basis, and cannot reasonably be compared to historical effluent limits.

Although there are many problems with Dr. Wells' calculation methodology, I have provided several specific examples below. First, Dr. Wells presumes that emissions from Latty Avenue dryer operations would instantaneously mix with an arbitrary volume of air, contained in an imaginary box. In contrast, air dispersion models use site-specific information and representative meteorological data to model the pollutant plume released from an emission source and calculate concentrations at user-specified locations, depending on the plume's location, height, and concentration profile. The difference between a state-of-the-science dispersion model and Dr. Wells' crude box model is illustrated in Figures 4-1a-b and 4-2, respectively.

[51] Wells, J. 2019b. Videotaped Deposition of James T. Wells, Ph.D. [transcript]. October 17. p. 153

[52] Reinke, P. and C. Keil. 2009. Well-Mixed Box Models in Mathematical Models for Estimating Occupational Exposure to Chemicals. A Publication by American Industrial Hygiene Association.

Figure 4-1a: Example of plume observed at the Brookhaven National Laboratory[53]

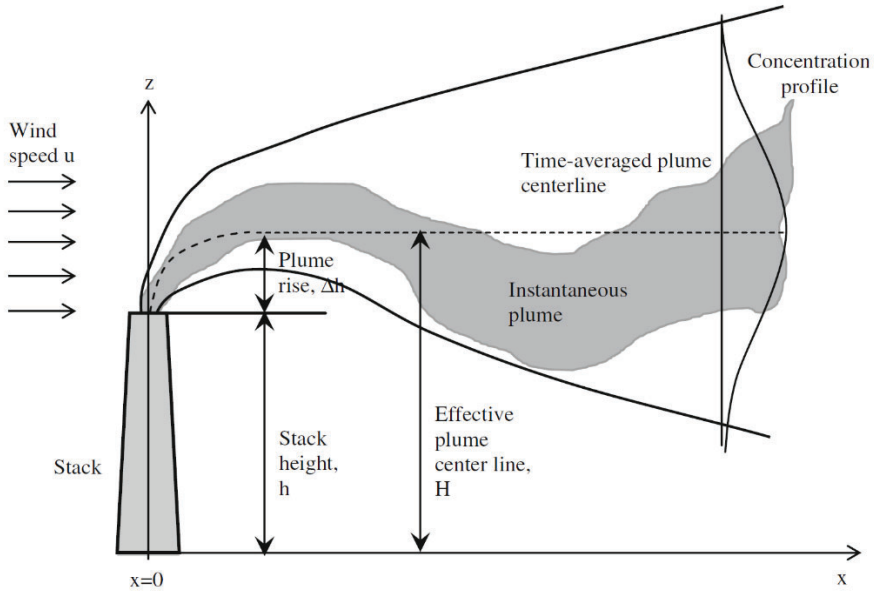

Figure 4-1b: Schematic representation of Gaussian plume dispersion[54]

[53] Slade, David H. 1968. Meteorology and Atomic Energy. US Atomic Energy Commission Office of Information Services. July. p. 110

[54] Tan, Zhongchao. 2014. Air Pollution and Greenhouse Gases: From Basic Concepts to Engineering Applications for Air Emission Control.

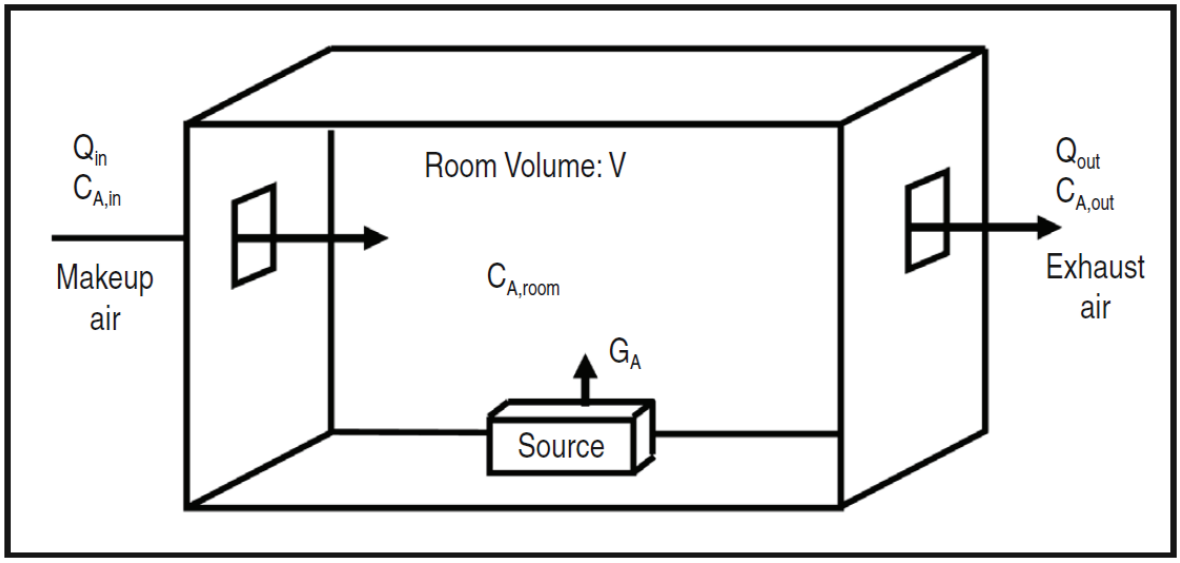

Figure 4-2: Conceptual Model of the Well Mixed Box[55]

Moreover, the dimensions of Dr. Wells' box are arbitrary and without scientific basis. Dr. Wells ignores the actual geometry of the Latty Avenue site and crudely represents this rectangular site as a perfect square. He then assumes the square has an arbitrary height of 10 m, meaning that emissions will instantaneously and completely mix within the first 10 m of air above the ground surface, but never rise any higher into the atmosphere.

> *A. For my own calculations, I assumed that the air mass that I was evaluating had a thickness of 10 meters.*
> *Q. Did you assume any instant distribution of contamination through this box that you created?*
> *A. I assumed a uniform distribution.*[56]

Dr. Wells provides no additional explanation or factual basis for this assumption and it is evident that emissions from the 9.1 m tall dryer stack[57] would have reached heights in excess of 10 m. That is, if a pollutant plume is released from a stack with an initial upward velocity or elevated temperature, the plume is said to be buoyant and will rise in the atmosphere as it travels downwind. According to the RAC report that Dr. Wells relies on for his analysis, the dryer stack had a minimum flow rate of 37,000 cubic feet per minute (CFM) and an operating temperature between 200 and 500 degrees Fahrenheit (°F).[58] Thus, emissions from the nearly 10 m tall dryer stack were buoyant and the resulting pollutant

[55] Reinke and Keil 2009, Figure 4.1

[56] Wells, J. 2019b, p. 314

[57] Barber-Greene Spec Sheet, January 1955

[58] Risk Assessment Corporation, Inc. (RAC). 2018. Reconstruction of Plaintiff Doses Associated with Residues Stored at the St. Louis Airport Storage Site and the Hazelwood Interim Storage Site and Critique of Opinions by Dr. Cheremisinoff, Ms. Sears and Dr. Clark. April 27. p. 6-13

plume would have continued to rise in the atmosphere, rather than being confined within an arbitrary 10 m tall box (as illustrated in Figure 4-1b).

While air dispersion models, including AERMOD and AERSCREEN, use peer-reviewed algorithms to account for plume rise and calculate the final height of a modeled pollutant plume,[59] Dr. Wells' box model is inherently incapable of representing a buoyant pollutant plume, which he admits in his deposition.

> *Q Did you make any assumptions concerning temperature?*
> *A There's -- there's no explicit assumptions about temperature in my calculations.*[60]

Further, Dr. Wells' predictions are extremely sensitive to box height, as any increase in box height proportionally increases the volume of air over which radionuclide emissions are diluted. As an illustration, if one were to increase his arbitrary box height to 20 meters, Dr. Wells' predicted concentrations would decrease by 50%.

In addition to representing the Latty Avenue site as an imaginary box, Dr. Wells' calculations also assume that winds blow over the site in a constant direction. Not only is this untrue, but it presumes that a single location along the site perimeter will always be downwind of Dr. Wells' emission source. In reality, wind direction varies over the course of a given day or year. Air dispersion modeling professionals use diagrams called wind roses to depict the frequency with which winds blow in various directions. In fact, RAC includes a wind rose displaying wind speeds and directions at the nearby St. Louis Lambert International Airport (located adjacent to SLAPS and within two miles of the Latty Avenue site) between 2008 and 2012. This wind rose is excerpted below and indicates that winds most frequently blew from the west-northwest; however, winds blew from this direction less than 10% of the time. This illustrates that any sort of modeling methodology that assumes winds only blow in a single direction will significantly overstate average pollutant concentrations. Moreover, despite the information contained in Dr. Wells' primary reference, at his deposition, Dr. Wells admitted that he does not know the prevailing wind direction at the site and does not consider wind direction to be an important factor in his analysis;[61,62] which is contrary to air dispersion science, given winds vary in both direction and speed and this variability affects predictions of airborne concentrations from air emission sources.

[59] Briggs, G. A., 1984., Plume rise and buoyancy effects. Atmospheric Science and Power Production, and Randerson, D., U.S. Dept. of Energy, 327-366pp. as cited in USEPA. 2004c. AERMOD: Description of Model Formulation. EPA-454/R-03-004

[60] Wells, J. 2019b, p. 315

[61] Wells, J. 2019b, p. 336

[62] Dr. Wells acknowledges, however, that wind direction would be important "if one was trying to do a more detailed analysis" (Wells, J. 2019b, p. 336)

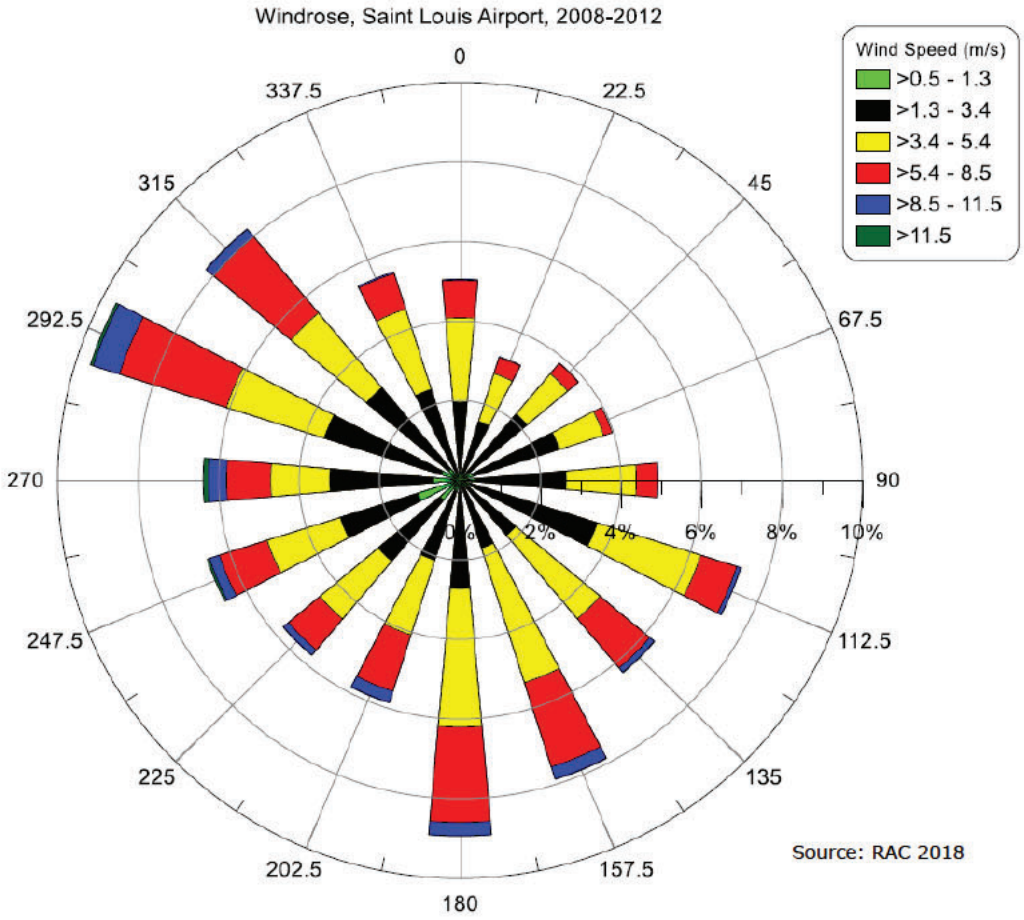

Figure 6-2. Wind rose for the St. Louis Airport from 2008 to 2012.

Dr. Wells' methodology also presumes that the dryer operation emissions were released at a constant rate in his calculations. This assumption disregards the dryer operation's daytime only operating schedule and fails to differentiate between daytime and nighttime meteorological conditions. Within the field of air dispersion modeling, there is a general understanding that the radiant heating and cooling of the earth's surface cause diurnal fluctuations in atmospheric stability. This affects how pollutants mix and disperse in the air adjacent to the earth's surface (the "boundary layer"). After sunset, the ground surface cools and atmospheric stability increases. When the sun rises, solar radiation heats the ground surface and the air adjacent to it. The warm air rises, generating turbulence and unstable atmospheric conditions. This facilitates pollutant dispersion and tends to decrease ground level pollutant concentrations.[63] Not only do Dr. Wells' calculations fail to account for varying emissions and meteorological conditions, but they are wholly incapable of representing the key meteorological parameters (e.g., solar radiation, air temperature) that affect atmospheric stability and turbulence. Thus, by simply selecting an approved air dispersion model, Dr. Wells could have

[63] Seinfeld, J. and Pandis, S. 2006. Atmospheric Chemistry and Physics. John Wiley & Sons, Inc. Hoboken, NJ. p. 731-32

more accurately represented Latty Avenue dryer operations, emissions from these operations, and the atmospheric dispersion of these emissions, but he chose not to do so.

In addition to these methodological errors, Dr. Wells fails to correctly implement the methodology he describes in his report. For example, he mistakenly assumes that there are 120 days in a quarter or 480 days in a year (there are 365 days in a non-leap year) and fails to identify an obvious error in the emission rate he relies on for his analysis, as discussed in detail in the following opinion. These errors further undermine the credibility of his calculated fenceline concentrations, and it is evident that these concentrations have no basis in accepted science and cannot reasonably be compared to historical effluent limits.

4.3 Application of a USEPA-Approved, Screening-Level Air Dispersion Model (AERSCREEN) Confirms that Dr. Wells' Box Model Significantly Overstates Radionuclide Concentrations

Although Dr. Wells relies on RAC for almost all the site-specific information he includes in his report, his analysis for the dryer ignores that RAC used the USEPA-approved air dispersion model, AERMOD, to evaluate airborne concentrations near the Latty Avenue site (described in Section 6 of the RAC Report). For example, when asked why he did not apply a Gaussian plume model, such as AERMOD or AERSCREEN, Dr. Wells cites a "paucity of data."[64] However, RAC discusses almost all of the simple inputs required to run a screening-level air dispersion model for the Latty Avenue dryer operation and summarizes most of these data in a single table within the RAC report, which I have reproduced below.[65,66]

Table 6-2. Release Parameters for HISS Dryer

Parameter	Value	Units
Building coordinate pairs (UTME, UTMN)	730154, 4294324; 730154, 4294356; 730189, 4294356; 730189, 4294324	meters
Stack location (UTME, UTMN)	730164, 4294324 Elevation: 152	meters
Stack height	9.14	meters
Stack diameter	2.74	meters
Flow rate	17.46	$m^3\ s^{-1}$
Release velocity	2.96	$m\ s^{-1}$
Release temperature	366	Kelvin

Had Dr. Wells chosen to use these inputs to apply a simple and conservative (i.e., will overestimate concentrations) screening-level dispersion model, such as USEPA's AERSCREEN, rather than a box

[64] Wells, J. 2019b, p. 316

[65] RAC 2018, Table 6-2

[66] Release Parameters for HISS Dryer. Additional relevant parameters used in RAC's modeling effort, including use of rural dispersion coefficients and building height, are further detailed in sections 6.2.6 and 6.3.3 of the RAC report, respectively. AERSCREEN defaults were utilized for terrain, receptor, and meteorological selections, and the dominant surface and climate profile inputs to AERSCREEN were assumed to be cultivated land and average moisture, respectively.

model, his fenceline concentrations would have been substantially lower than the estimates he provides in his report (see Opinion 3).

It is particularly significant that a screening model, such as AERSCREEN, provides substantially lower concentration estimates than Dr. Wells' box model. AERSCREEN is specifically designed to overpredict air concentrations and is intended as a screening tool to determine whether a more refined modeling analysis is necessary. For example, unlike a more refined dispersion model, AERSCREEN evaluates maximum downwind concentrations under worst-case meteorological conditions, even if these conditions are unlikely or infrequent at a particular site. Further, AERSCREEN provides maximum concentrations in the direction where impacts are expected to be the greatest. For a site such as Latty Avenue, where the source is located near the edge of the property, maximum modeled concentrations may correspond to an on-site location (e.g., a location 50 m away from a source may be off-site in one direction and on-site in another). A more refined analysis would evaluate the location of maximum impact, given the site geometry and worst-case meteorological conditions. Finally, AERSCREEN does not fully consider the impact of the dryer operation only occurring during daytime hours when dispersion conditions tend to be most favorable. Thus, it is evident that a more refined model, such as USEPA's AERMOD, would further reduce concentration estimates at the Latty Avenue fenceline. The fact that AERSCREEN produces lower modeled concentrations than Dr. Wells' box model illustrates the significant degree to which his box-calculation methodology inflates his results.

5. OPINION 2: DR. WELLS SUBSTANTIALLY OVERSTATES HISTORICAL RADIONUCLIDE EMISSIONS FROM COTTER'S LATTY AVENUE DRYING OPERATIONS.

In his expert report, Dr. Wells opines that "waste drying operations" at the Latty Avenue site released radioactive material into the air[67] and that these releases resulted in exceedances of the 10 CFR §20.106 effluent limits for both Th-230 and Pa-231 in air.[68] To arrive at this opinion, Dr. Wells relies on particulate matter (PM) emission rates that Dr. Till et al. of RAC developed for the Latty Avenue drying operations during a previous litigation. Although Dr. Wells has not reproduced RAC's emission calculations[69] nor read the entire RAC report in detail,[70] he endorses their emission estimation methodology.

> *I have reviewed RAC's calculations and although it must be acknowledged that there is considerable uncertainty in these calculations, they are reasonable estimates of releases to air during drying operations.*[71]

It is evident that Dr. Wells endorses and adopts these emission rates without adequate consideration, as:

1. He fails to identify an obvious error in RAC's emission calculations, which overstate PM releases to air; and
2. He either ignores or fails to address RAC's explanation of how the drying operation emission rates were conservatively calculated (i.e., "overestimated"), specifically during Cotter's 1970 to 1971 drying campaign.[72] Dr. Wells should have evaluated the potential impact of these conservative emission estimates on his results, given that he opines that effluent limits in air were exceeded.

Each of these items are discussed further below.

5.1 Dr. Wells Repeats a Calculation Error in the RAC Report

RAC calculates PM emissions from Latty Avenue drying operations using an emission factor and particle size distribution from the USEPA's AP-42: Compilation of Air Emissions Factors. RAC claims that the AP-42 emission factor presented in Chapter 11, Section 24, "Metallic Minerals Processing" for "drying—all materials except titanium/zirconium sands (SCC 3-03-024-11)"[73] was developed for a process analogous to the dryer system used at the Latty Avenue site and was therefore appropriate to use for their assessment.[74] I have not specifically evaluated the representativeness of this emission

[67] Wells, J. 2019a, p. 17

[68] Id, p. 18

[69] Wells, J. 2019b, p. 304

[70] Id, p. 70-71

[71] Wells, J. 2019a, p. 17

[72] RAC 2018, pg. 4-52 – 4-53

[73] USEPA. 1995. AP-42. 11.24 Metallic Mineral Processing. August. Available online at https://www3.epa.gov/ttn/chief/ap42/ch11/final/c11s24.pdf

[74] RAC 2018, p. 4-57

factor and reserve the right to further evaluate this emission factor at a later date. However, based on the documentation provided in AP-42, it is evident that RAC misapplied the emission factor they selected.

Equation 4-26 of the RAC report demonstrates that RAC multiplied the AP-42 emission factor by the "Dryer Feed [Wet Mg]" to calculate historical emissions, which is incorrect.[75] Instead, this emission factors should clearly be multiplied by "**the weight of material exiting dryer**" [emphasis added] (see footnote to AP-42 emission factor table).[76] Since the dryer was used to remove moisture from the residues, the weight of material exiting the dryer was lower than the weight of material fed to the dryer. Hence, air emissions calculated using the correct weight of material would be lower than those RAC calculated. Dr. Wells fails to correct and repeats this error, highlighting his lack of scientific rigor in understanding the factors he indiscriminately draws from others to use in his report.

While I am not necessarily in agreement with the application of the 11.24 AP-42 emission factors to Latty Avenue dryer operations, I have used this emission factor with the intended input parameter (i.e., using weight exiting the dryer) in Table 5.1 to illustrate the impact of RAC's calculation error, which forms the basis for Dr. Wells' analysis. This revision reduces emissions from drying operations by 10% (see Table 5-1).

5.2 Dr. Wells Does Not Adequately Address the Impact of RAC's Overestimated Emission Rate on His Conclusions

In addition to repeating the calculation error, Dr. Wells fails to acknowledge the inherent conservatism of RAC's approach. Specifically, the RAC report states that

> *[t]he temperature to the dryer was decreased in October 1970 in response to a letter from the St. Louis County Health Department, Division of Air Pollution Control (PKF 1970). This is clearly seen in the "as shipped" moisture percentages provided in the shipping receipts (see Figure 4-7).* ***This would result in lower emissions but is not considered explicitly in this analysis*** [emphasis added][77]

As Cotter's drying campaign ran from August 1970 to February 10, 1971, by RAC's account, Dr. Wells overstates emissions during all but the first two months of Cotter's operations. Although regulators and risk assessors often use conservative assumptions as part of an initial screening analysis to evaluate whether a more detailed analysis is required, these same conservative assumptions cannot be used to demonstrate that concentrations exceeded a regulatory limit. That is, if calculated concentrations are below an applicable limit, even using conservative assumptions that overstate impacts (e.g., higher than actual emission rates), one can safely conclude that no additional analysis is necessary. However, if screening results fail to meet a regulatory limit, it is not possible to conclude that concentrations would be above this limit, only that a more refined analysis may be necessary.

[75] Id, p. 4-61

[76] USEPA 1995, Table 11.24-1

[77] RAC 2018, p. 4-57

Despite these well-established practices, Dr. Wells uses RAC's inflated emission estimate to conclude that, for example, "thorium-230 exceeds the 10 CFR effluent guideline for air in each quarter."[78]

[78] Wells, J. 2019a, p. 18

Table 5-1. Correction to RAC's Drying Operations Emission Estimates for Cotter's Operational Period (1970-1971)

Year and quarter	Dryer feed (wet tons)[1] AM-7[4]	Total PM_{10} released (tons), RAC report[2] AM-7[4]	Shipped quantity (wet tons)[1] AM-7[4]	Total PM_{10} released (tons), Revised Input[3] AM-7[4]
1970 Q3	7,875	1.00	7,125	0.90
1970 Q4	12,812	1.62	11,244	1.42
1971 Q1	7,056	0.89	6,522	0.82
1971 Q2	0	No material dried	9,525	No material dried
Cotter Total	27,743	**3.51**	34,416	**3.15**
			Percent Reduction (%)	**10**

Notes:

[1] Quantities taken directly from RAC report (2018), Table 4-27.

[2] PM_{10} releases taken directly from RAC report (2018), Table 4-33.

[3] PM_{10} releases corrected to AP-42 stated applicable input of weight exiting the dryer: "Shipped quantity (wet tons)" taken from RAC report (2018), Table 4-27.

[4] Only AM-7 was dried during Cotter's operational period (1970-1971).

6. OPINION 3: AIR CONCENTRATIONS FROM COTTER'S LATTY AVENUE OPERATIONS WOULD BE BELOW EFFLUENT LIMITS USING DR. WELLS' APPROACH AFTER CORRECTING FOR OMISSIONS AND ERRORS IDENTIFIED IN HIS ANALYSIS, INCLUDING HIS APPLICATION OF AN UNSCIENTIFIC BOX MODEL.

Due to the issues discussed in my first two opinions, it is evident that Dr. Wells' predicted fenceline radionuclide concentrations are both scientifically unreliable and substantially inflated. If one were to revise the identified errors and omissions discussed in my first two opinions, and apply a scientifically-accepted screening-level air dispersion model, fenceline concentrations would be considerably lower than the concentrations he predicts in his report.[79,80] The revised fenceline concentrations during Cotter's operations would also fall below 10 CFR §20.106 effluent limits, invalidating Dr. Wells' conclusions on radionuclide releases from the Latty Avenue site during this time period. Further refined analysis using more complex air dispersion modeling would be expected to result in even lower concentrations, but is unnecessary since conservative (i.e., overestimated) screening-level results during the Cotter period are below the effluent limits.

The various revisions to address Dr. Wells' erroneous and unscientific calculations are described in the following sections and revised fenceline concentrations of those constituents he opines are over the effluent limits are compared to Dr. Wells' initial predictions and appropriate effluent limitations in Tables 6-1 and 6-2 at the end of this section.

6.1 Dr. Wells Uses Erroneous Averaging Periods

In his expert report, Dr. Wells states that he was asked to

> *provide opinions and analysis related to certain information requirements specified in Case Management Order No. 14 for Future Consolidated Cases Filed Against Cotter Corporation (NSL) and/or Mallinckrodt LLC, dated October 15, 2018.*[81]
>
> *The Case Management Order requires plaintiffs to determine the concentrations of effluent discharges at the boundary of the SLAPS and Latty Avenue sites allegedly attributable to Mallinckrodt's and/or Cotter's operations and whether such*

[79] Herein, the term "fenceline" concentration refers to the maximum concentration at or beyond the nearest fenceline distance from the dryer stack for the screening-level air dispersion modeling analysis I performed using AERSCREEN. Since AERSCREEN uses only the nearest fenceline distance in all direction from the source, the maximum concentration reported by the model could be on-site for several other wind directions from the source. Therefore, the AERSCREEN results represent a conservative estimate of the maximum fenceline concentration.

[80] Analogous to RAC's approach, I have not attempted to revise the emission rate in Dr. Wells' approach to account for the decrease in dryer temperature to the dryer in October 1970 since RAC's emission rates are conservative (overestimated) and my analysis demonstrates the revised fenceline concentrations during Cotter's operations are below 10 CFR §20.106 effluent limits (see section 5.2 for details) without this correction that would lower the concentrations further.

[81] Id, p. 1

concentrations exceed the effluent limitations found in applicable federal regulations: 10 CFR §20.106(a), Appendix B.[82]

10 CFR Part 20 limits the concentration of various radionuclides in air and water that may be released from a facility to an "unrestricted area."[83] 10 CFR Part 20 notes that "concentrations may be averaged over a period not greater than one year"[84] and, as discussed in further detail in Jason Miller's expert report, these effluent limits are derived from annual dose limits.[85] The concentrations that Dr. Wells compares to the 10 CFR §20.106 effluent limits (see Table 3 of his report) are for the individual quarters in 1968, 1970, and 1971 when the dryer was operating rather than an annual basis that corresponds to the derivation of the effluent limits.

It is possible to calculate annual average concentrations from Dr. Wells' quarterly numbers. Cotter's drying operations occurred for less than a year and drying operation emissions and resulting fenceline concentrations were zero during quarters 1 and 2 (Q1-Q2) of 1970 and Q2-Q4 of 1971. Thus, had Dr. Wells calculated annual average concentrations (either on a calendar or operational year basis), these concentrations would have been significantly less than the quarterly numbers he provides in Table 3 of his report.

6.2 Dr. Wells Incorrectly Applies the Emission Rate He Selectively Chooses from RAC's Report

Dr. Wells adopts RAC's drying operation emission rate without reviewing its basis and fails to identify a calculation error. This error inflates drying operation emissions by at least 10% during the Cotter period and likely more given the inherent conservatism of RAC's approach for the Cotter period, as discussed in my Opinion 2.[86]

6.3 Use of a Scientific Screening (i.e., Conservative Model Designed to Over-Estimate Concentrations) Air Dispersion Model, such as AERSCREEN, Rather than Dr. Wells' Box Model, Would Result in Lower Predicted Concentrations

As discussed in Opinion 1, Dr. Wells uses a crude box model, rather than a more scientifically reliable air dispersion model, to estimate radionuclide concentrations at the Latty Avenue fenceline. Although Dr. Wells appears to claim that there was insufficient data to reliably apply a Gaussian plume model,

[82] Id, p. 12

[83] 10 CFR Part 20 defines an unrestricted as area as "any area access to which is not controlled by the licensee for purposes of protection of individuals from exposure to radiation and radioactive materials, and any area used for residential quarters." The Plaintiffs have taken this to mean any area outside of the property boundary and have calculated "fenceline" concentrations for comparison to the limit.

[84] United States Atomic Energy Commission. 1969. Standards for Protection Against Radiation [Revised]. 10 CFR Part 20.

[85] Miller, J. 2020. Expert Report of Jason B. Miller in the Matter of Pamela Butler, et al. v. Mallinckrodt, LLC, et al. March. Section 6.1.2

[86] I note that in Mr. Zoch's expert report that he reports dryer emissions were about 33% less than estimated in the RAC report and utilized by Dr. Wells in his analysis. This is equivalent to approximately 25% lower on average than the Dr. Wells' corrected values presented in my Table 5-1 so concentrations in my report would also be an additional 25% lower if I use Mr. Zoch's emission rates (Zoch 2020, Table 18). However, I chose not to use Mr. Zoch's dryer emissions at this time, as it is unnecessary since my conservative (i.e., overestimated) screening-level results during the Cotter period are already below the effluent limits (see Table 6-2).

such as AERMOD or AERSCREEN, the RAC report that Dr. Wells relies on for the remainder of his analysis provides the inputs required to run AERSCREEN. That is not to say that the input parameters RAC developed are accurate, as I have not independently evaluated them, only that Dr. Wells selectively chooses specific information from the RAC report (e.g., drying operation emission rates), while ignoring other information. For illustrative purposes, I have applied AERSCREEN to calculate maximum, annual concentrations (conservatively based on an operational year) using Dr. Wells' emission rates, which I recalculated using the appropriate USEPA-specified input parameter, and the model input parameters that RAC developed for its own analysis. As expected, AERSCREEN produces substantially lower concentrations than Dr. Wells' box model.

AERSCREEN is a screening model and is designed to overstate actual concentrations at the point of maximum impact. Thus, if modeled concentrations are below regulatory limits, one can conclude that actual concentrations would also be below these limits (provided the model inputs are, in fact, representative) and no additional analysis is required. This is the case for drying operations during the Cotter period, as shown in Table 6-2, and it is evident that Dr. Wells' conclusion that concentrations during this period exceeded effluent limits is incorrect.

Conversely, since AERSCREEN is designed to provide a "preliminary or conservative estimate,"[87] AERSCREEN results above a regulatory limit would not necessarily indicate an actual exceedance of this limit, only that a more refined analysis may be necessary. A more refined analysis using USEPA's AERMOD would typically be expected to result in lower concentrations and USEPA studies have found that AERSCREEN typically produces results that are between one and seven times greater than AERMOD.[88] Thus, actual air concentrations due to Latty Avenue drying operations would typically be expected to be even lower than the numbers provided in Tables 6-1 and 6-2.

6.4 While Dr. Wells Selectively Chooses to Rely on the Emission Rate from the RAC Report, He Ignores Other Information Such as the Soluble/Insoluble Fractions of the Materials Modeled

In addition to selectively choosing his model input data, Dr. Wells also ignores RAC's characterization of the solubility of the material released from the SLAPS and Latty Avenue sites as well as RAC's selection of the most appropriate effluent limits to apply at these sites. 10 CFR §20.106 provides separate limits for the soluble and insoluble forms of various radionuclides, including U-238, Th-230, and Pa-231. Although RAC concludes that the residue materials at issue in this case are largely insoluble, Dr. Wells selects the lower soluble limits for his comparison. RAC states that,

> *Based on process knowledge and a chemical analysis performed by Dick Duffey of the University of Maryland (Duffey 1986), uranium was present in process residues as a carbonate or hydrated oxide (AEC 1973), which is insoluble in water (Zavodska et al. 2008). According to Duffey's analysis (1986), the 230Th and 232Th produced in the MCW process were insoluble.*[89]

[87] USEPA 2017

[88] Thurman, J. 2008

[89] RAC 2018, p. 4-9

RAC also uses the 10 CFR §20.106 effluent limits (described as non-occupational maximum permissible concentrations or MPCs for unrestricted use) to evaluate monitoring data collected at the SLAPS and Latty Avenue sites. The non-occupational MPC that RAC selects for their analysis is "2 pCi m^{-3} for natural **insoluble** uranium" [emphasis added].[90]

Given the numerical differences in soluble and insoluble effluent limits, as shown in Table 6-2, it is unreasonable for Dr. Wells to have ignored this information, particularly given his endorsement of the RAC report, based on his adoption of their emission rate. While I have not specifically validated RAC's analysis, their conclusions largely agree with Mr. Zoch's solubility numbers, which are summarized in Table 6-2. Table 6-2 also compares Dr. Wells' revised model results to the appropriate effluent limits using Mr. Zoch's solubility numbers. Based on this analysis, it is evident that Dr. Wells' use of the lower soluble limits is not only unreasonable but contributes to his erroneous conclusion that air concentrations at the site historically exceeded regulatory limits.

As shown in 6-2, if one were to correct the identified errors and omissions in Dr. Wells analysis, calculated concentrations during Cotter's operations would have been below effluent limits. And, given the conservatism built into this illustrative analysis, actual concentrations due to drying operations are likely to have been much lower.

Table 6-1: Annualized Comparison of Dr. Wells' Predictions to Revised Fenceline Radionuclide Concentrations for Cotter's Operational Period (1970-1971)

Isotope	Dr. Wells' Annualized ($pCi\ m^{-3}$)[1]	AERSCREEN, Annualized Maximum ($pCi\ m^{-3}$)[2]	% Reduction[3]
^{230}Th	0.41	0.22	45%
^{231}Pa	0.024	0.013	44%

Notes

[1] Calculated from quarterly results in Table 3 of Dr. Wells' Report. Annualized for period Q3/70 to Q1/71.

[2] Includes revisions from overstated emissions (see Table 5-1) and use of AERSCREEN. Annualized for period Q3/70 to Q1/71.

[3] Variation in percent reduction due to rounding.

[90] RAC 2018, p. 10-3

Table 6-2: Comparison of Dr. Wells' Revised Fenceline Radionuclide Concentrations from Latty Avenue Dryer Operations to 10 CFR §20.106 Effluent Limits for Cotter's Operational Period (1970-1971)

Total Concentration: Soluble and Insoluble Fractions		
Isotope[1]	**Solubility (%)[2]**	**AERSCREEN, Annualized Maximum – Total Soluble + Insoluble Fractions ($pCi\ m^{-3}$)[3]**
^{230}Th	<1	0.22
^{231}Pa[4]	<0.1	0.013
Soluble Fraction		
Isotope	**Soluble Effluent Limits ($pCi\ m^{-3}$)**	**AERSCREEN, Annualized Maximum – Soluble Fraction ($pCi\ m^{-3}$)**
^{230}Th	0.08	0.0022
^{231}Pa	0.04	0.000013
Insoluble Fraction		
Isotope	**Insoluble Effluent Limits ($pCi\ m^{-3}$)**	**AERSCREEN, Annualized Maximum – Insoluble Fraction ($pCi\ m^{-3}$)**
^{230}Th	0.3	0.22
^{231}Pa	4	0.013

Notes:

[1] Results provided for isotopes Dr. Wells claims exceeded effluent limits.

[2] Source: Zoch 2020, Table 4

[3] Includes revisions from overstated emissions (see Table 5-1) and use of AERSCREEN. Annualized for period Q3/70 to Q1/71.

[4] Protactinium-231 was not "sufficiently soluble for detection in leachate, indicating solubilities of <0.10%" (Zoch 2020, Table 4)

7. OPINION 4: RADON CONCENTRATIONS FROM COTTER'S LATTY AVENUE OPERATIONS WOULD BE BELOW THE EFFLUENT LIMIT USING READILY AVAILABLE INFORMATION SPECIFIC TO LATTY AVENUE FROM DR. WELLS' PRIMARY REFERENCE; CONTRARY TO DR. WELLS' ERRONEOUS, BIASED HIGH, SCIENTIFICALLY FLAWED METHODOLOGY.

Although Dr. Wells uses a different approach to calculate radon releases from the Latty Avenue site, he once again relies on selective information from the 2018 RAC report. It is evident that he fails to validate or appropriately apply this information, as he applies an emission rate developed for the primary radon emission source at **SLAPS** to the Latty Avenue site.[91] In doing so, he relies on a dispersion factor that RAC developed to represent **remedial activities** occurring between **1998 and 2011**, rather than a factor representative of the site **operations** in the **1960s and 1970s**.[92] Additionally, Dr. Wells ignores other information in the RAC report, including a more relevant analysis of radon emissions from storage piles, which produces emission rates several orders of magnitude lower than the values Dr. Wells uses in his analysis, and would have resulted in concentrations below the effluent limit in 10 CFR §20.106 using Dr. Wells calculation approach. As a result, it is evident that Dr. Wells' radon calculations are unreliable and that he significantly overstates radon concentrations at the Latty Avenue fenceline.

7.1 Dr. Wells Mistakenly Uses a Radon Emission Rate that RAC Developed for SLAPS and Applies It to the Latty Avenue Site

In his attempt to estimate fenceline radon concentrations at the Latty Avenue site, Dr. Wells selectively chooses a 1.2×10^{-4} curie per second (Ci/s) radon release rate from page 4-35 of the RAC report. Even a cursory review reveals that this value is for the **K-65** (a material that was not present at Latty Avenue) drum storage area at **SLAPS**, as he excerpts this value from section 4.5.5.1, titled "Radon Emissions from K-65 Drums." Additionally, the first sentence in this section states that, "Fifty-five gallon drums containing radium-bearing **K-65** material were stored at **SLAPS** from **1946 to 1949**" [emphasis added].[93] Further review of this section reveals that RAC calculated this 1.2×10^{-4} Ci/s release rate using measurements collected downwind of the K-65 storage area[94] between 1948 and 1949 and a Gaussian plume model specifically designed to evaluate emissions from the drum storage area at SLAPS.[95] Thus, it is clear that the radon concentrations that Dr. Wells develops for the

[91] RAC 2018, p. 4-35

[92] RAC 2018, p. 4-32

[93] RAC 2018, p. 4-34

[94] "The average radon concentration was calculated assuming values reported as 'less than' were equivalent to the 'less than' value, and non-detects were the minimum 'less than' value of 3 pCi L^{-1} (RAC 2018, p. 4-35)." This conservative assumption causes RAC to overstate the average radon concentration and radon release rate at SLAPS.

[95] RAC 2018, p. 4-34 - 4-35

Latty Avenue site are in no way related to actual historical concentrations at this site. Additionally, as the K-65 material "dominated radon releases" at SLAPS during its short storage period in the late-1940s, Dr. Wells significantly overstates radon concentrations at the Latty Avenue fenceline, as discussed below.[96]

7.2 Dr. Wells' Incorrect Use of a SLAPS Emission Rate Causes Him to Seriously Overstate Radon Concentrations at the Latty Avenue Site

In addition to representing a methodological error, Dr. Wells' application of a SLAPS emission rate causes him to substantially overstate radon concentrations at the Latty Avenue site. For example, the RAC report provides estimates of total historical radon releases from both the SLAPS and Latty Avenue sites; while I did not validate these values, they illustrate Dr. Wells' significant inflation of Latty Avenue results. RAC calculates a total radon release from SLAPS of 65,234 Ci – dominated almost exclusively by releases from the K-65 drums (62,600 Ci), which were only present from 1946-1949 – while calculated releases from the Latty Avenue site were only 362 Ci.[97] Thus, the same report that provides the foundation for Dr. Wells' analysis indicates that radon emissions from the Latty Avenue site were several orders of magnitude lower (173 times lower) than emissions from the K-65 drums at SLAPS. Based on Dr. Wells' methodology, a reduction in radon emissions would correspond to a proportional decrease in calculated fenceline concentrations (i.e., they would be 173 times lower). Had Dr. Wells incorporated RAC's Latty Avenue total radon release information into his analysis,[98] he would have calculated a fenceline radon concentration of 0.043 pCi/L,[99] which is well below the 3.0 pCi/L effluent limit that he cites in his report.

Dr. Wells also ignores RAC's estimate of radon emissions from residue piles, which unlike the K-65 drums, were present at the Latty Avenue site. For example, RAC presents a radon flux model[100] for hypothetical AJ-4, AM-7, and AM-10 residue piles and estimates total radon flux rates from these piles using material-specific parameters. The results of this analysis are provided in Table 4-18 of the RAC report. While I have not validated RAC's calculations, the fluxes in Table 4-18 represent RAC's estimate of **maximum** total radon emissions from the residue piles at the two sites, as RAC specifically selects site-specific input parameters (i.e., residue pile area and thickness) to maximize these values.[101] RAC's conservative estimate of total radon emissions from the residue piles is approximately 4.0×10^{-6} Ci/s,[102] which is 30 times smaller than the erroneous value that Dr. Wells uses (1.2×10^{-4} Ci/s) in his analysis. Had Dr. Wells incorporated this emission rate into his analysis he

[96] RAC 2018, p. 4-67 – 4-68

[97] RAC 2018, Table 4-38

[98] The radon release rate Dr. Wells uses corresponds to RAC's estimate of radon emissions from the K-65 drums. As RAC provides total radon releases from both the K-65 drums (62,600 Ci) and Latty Avenue site (total of 362 Ci), the proportional difference between the two sources can be estimated.

[99] Dr. Wells used the equation **X = DF x Q**. **X** is the calculated concentration, **Q** (in Ci/s) is the emission rate discussed in the text, **DF** is the Dispersion Factor that Dr. Wells used from the RAC report (6.21x10-5 s/m^3) (Wells, J. 2019a, p. 14).

[100] RAC's radon flux model for pile emissions is based on methods described within the Radon Attenuation Handbook for Uranium Mill Tailings Cover Design by Rogers et al. (1984).

[101] RAC 2018, p. 4-34

[102] Determined as the combined total flux from each material in Table 4-18 of the 2018 RAC report.

Opinion 4: Radon Concentrations from Cotter's Latty Avenue Operations Would Be Below the Effluent Limit Using Readily Available Information Specific to Latty Avenue from Dr. Wells' Primary Reference; Contrary To Dr. Wells' Erroneous, Biased High, Scientifically Flawed Methodology.

would have calculated a fenceline radon concentration of 0.25 pCi/L,[103] which is also well below the 3.0 pCi/L effluent limit that he cites in his report.

Thus, Dr. Wells' conclusion that radon concentrations at the Latty Avenue fenceline exceeded the effluent limit cannot be supported, even using Dr. Wells' own methodology and readily available information in the primary reference that he relies on for his analysis that show radon concentrations are below the effluent limit.

[103] Dr. Wells used the equation **X = DF x Q**. **X** is the calculated concentration, **Q** (in Ci/s) is the emission rate discussed in the text, and **DF** is the dispersion factor that Dr. Wells used from the RAC report (6.21x10-5 s/m3) (Wells, J. 2019a. p. 14).

8. SUMMARY OF OPINIONS

1. Dr. Wells' analysis of fenceline radionuclide concentrations at the Latty Avenue site for comparison to historical regulatory effluent limits does not follow a scientifically valid methodology and contains several errors, which together substantially overstate airborne concentrations and make his analysis unreliable.

2. Dr. Wells substantially overstates historical radionuclide emissions from Latty Avenue drying operations.

3. Dr. Wells erroneously concludes that radionuclide concentrations at the Latty Avenue fenceline exceeded effluent limits. Radionuclide concentrations in air from Cotter's Latty Avenue operations would be below effluent limits using Dr. Wells' approach after correcting for his omissions and errors identified in his analysis, including his application of an unscientific box model.

4. Dr. Wells' evaluation of radon releases from the Latty Avenue site is erroneous, biased high, and does not follow a rigorous scientific methodology; thus, it is unreliable. Radon concentrations in air from Cotter's Latty Avenue operations would be below the effluent limit using readily available information specific to Latty Avenue from Dr. Wells' primary reference.

9. REFERENCES

Barber-Greene Spec Sheet, January 1955

Bates Numbered Documents: COTTER00000915, COTTER00001274-1282, COTTER00001818-9, COTTER00002645-54, COTTER00002760-64, COTTER00003142-3153, COTTER00003309, COTTER00003355-3357, COTTER00003360, COTTER00003362, COTTER00003365, COTTER00003368, COTTER00003371, COTTER00003374, COTTER00003377, COTTER00003407, COTTER00003413, COTTER00003421, COTTER00003424, COTTER00003436, COTTER00004257, COTTER00004263, COTTER00004269, COTTER00004275, COTTER00004278, COTTER00004557, COTTER00004559, COTTER00004561, COTTER00004568, COTTER00004571, COTTER00004840, COTTER00005485-98, COTTER00005510-5518, COTTER00005524-5530, COTTER00006041, COTTER00006248-6249, COTTER00009696, MLCT 0000143086, MLCT_0000152155-78, MLCT_TParty_0000084-87, MLCT_Tparty_0000102, Plaint00032695

Bentley, L., T. Bowie, G. Hoch, and D. Daugherty. 2007. Specification of Surface Parameter Values for the AERMET Preprocessor for Geographical Areas with Atypical Seasonal Patterns. 2007 Annual AWMA Meeting. Pittsburgh, PA. June.

Buck, Alice. 1983. The Atomic Energy Commission, U.S. Department of Energy Office of History and Heritage Resources. July.

Daugherty, D. D., W. Li, K. Mertz, and S. Hayes. 2003. The Importance of Surface Roughness Selection in AERMOD Modeling for Shoreline Sources. Paper 81161. 2003 Annual Meeting, Air & Waste Management Association, San Diego, CA. June.

Harrington, C.D. and A.E. Ruehle. 1959. Uranium Production Technology. D. Van Nostrand Company, Inc. Princeton, NJ.

Hoch, G., C. Barney, and D. D. Daugherty. 2006. A Case Study in Meteorological Monitoring: Evaluation of Potential Impacts on Data Quality Using Non-Traditional Data Analysis Techniques. Paper 495. 2006 Annual Meeting, Air & Waste Management Association, New Orleans, LA. June.

Miller, J. 2020. Expert Report of Jason B. Miller in the Matter of Pamela Butler, et al. v. Mallinckrodt, LLC, et al. March.

Mukai, C., T. Bowie, G. Hoch, and D. Daugherty. 2007. Evaluation of Urban Boundary Layer Parameters in AERMOD or Poorly-Defined Urban Areas. 2007 Annual AWMA Meeting. Pittsburgh, PA. June.

National Research Council (NRC). 1994. Science and Judgment in Risk Assessment. National Academy Press, Washington DC.

Oak Ridge Associated Universities (ORAU), Dade Moeller, and MJW Technical Services ("ORAU Team"). 2010. Basis for Development of an Exposure Matrix for the Mallinckrodt Chemical Company St. Louis Downtown Site and the St. Louis Airport Site, St. Louis, Missouri ("Dose Reconstruction Project for NIOSH"). November 22.

Payer, B. W., S. Lee, G. M. Hoch, and D. D. Daugherty. 2008a. Assessing the Uncertainty from Source Selection and Representation for Mobile Emission Source Activities in Air

Dispersion Modeling Assessment of Goods Movement Facilities. Poster presented at Transportation Research Board of the National Academies Data for Goods Movement Impacts on Air Quality Conference, Irvine. March.

Payer, B. W., S. Lee, G. M. Hoch, and D. D. Daugherty. 2008b. Evaluation of Source Selection and Representation for Mobile Emission Source Activities on Air Dispersion Modeling Setup Time, Run Time, and Modeling Results Using AERMOD. Presented at 2008 Annual Meeting, Air & Waste Management Association, Portland, Oregon. June.

Reinke, P. and C. Keil. 2009. Well-Mixed Box Models in Mathematical Models for Estimating Occupational Exposure to Chemicals. A Publication by American Industrial Hygiene Association.

Risk Assessment Corporation, Inc. (RAC). 2018. Reconstruction of Plaintiff Doses Associated with Residues Stored at the St. Louis Airport Storage Site and the Hazelwood Interim Storage Site and Critique of Opinions by Dr. Cheremisinoff, Ms. Sears and Dr. Clark. April 27.

Rogers, V.C., Nielson, K.K., and D.R. Kalkwarf. 1984. Radon Attenuation Handbook for Uranium Mill Tailings Cover Design. Prepared for U.S. Nuclear Regulatory Commission. NUREG/CR-3533, PNL-4878, RAE-18-5.

Seinfeld, J. and Pandis, S. 2006. Atmospheric Chemistry and Physics. John Wiley & Sons, Inc. Hoboken, NJ.

Slade, David H. (ed.) 1968. Meteorology and Atomic Energy. US Atomic Energy Commission Office of Information Services. July.

Tan, Zhongchao. 2014. Air Pollution and Greenhouse Gases: From Basic Concepts to Engineering Applications for Air Emission Control.

Thurman, J. 2008. AERSCREEN: Status and Update. 9th Modeling Conference. USEPA Support Center for Regulatory Atmospheric Modeling ("SCRAM"). October 9. Available online at: https://www3.epa.gov/scram001/9thmodconf/aerscreen_9thmc_1009.pdf

United States Atomic Energy Commission. 1969. Standards for Protection Against Radiation [Revised]. 10 CFR Part 20.

United States District Court, Eastern District of Missouri, Eastern Division. Complaint, Pamela Butler v. Mallinckrodt, Inc., et al. Case No. 4:18-CV-01701. 2018. Oct. 5.

United States District Court, Eastern District of Missouri, Eastern Division. Complaint, Kenneth Koterba v. Mallinckrodt, Inc., et al. Case No. 4:18-CV-01702. 2018. Oct. 5.

United States District Court, Eastern District of Missouri, Eastern Division. Complaint, Anthony Hines v. Mallinckrodt, Inc., et al. Case No. 4:18-CV-01703. 2018. Oct. 5.

United States District Court, Eastern District of Missouri, Eastern Division. Complaint, Emery David Walick v. Mallinckrodt, Inc., et al. Case No. 4:18-CV-01704. 2018. Oct. 5.

United States Environmental Protection Agency (USEPA). 1995. AP-42. 11.24 Metallic Mineral Processing. August. Available online at: https://www3.epa.gov/ttn/chief/ap42/ch11/final/c11s24.pdf

USEPA SCRAM. Air Quality Dispersion Modeling – Preferred and Recommended Models. Available online at https://www.epa.gov/scram/air-quality-dispersion-modeling-preferred-and-recommended-models. Last Accessed December 1, 2019.

USEPA. 2004a. Air Toxics Risk Assessment Reference Library Volume 1 Technical Resource Manual. EPA-453-K-04-001A.

USEPA. 2004b. Air Toxics Risk Assessment Reference Library. Volume 2. Facility-Specific Assessment. Office of Air Quality Planning and Standards. EPA-453-K-04-001B. April. Available online at: http://www.epa.gov/ttn/fera/data/risk/vol_2/volume_2-april_2004.pdf

USEPA. 2004c. AERMOD: Description of Model Formulation. EPA-454/R-03-004.

USEPA. 2016. AERSCREEN User's Guide. EPA-454/B-16-004.

USEPA. 2017. 40 CFR Part 51, Appendix W – Guideline on Air Quality Models. January 17.

Wells, J. 2019a. Expert Report of James T. Wells, PhD, PG in the matter of McClurg, et al. v. Mallinckrodt, Inc., et al. March 31.

Wells, J. 2019b. Videotaped Deposition of James T. Wells, Ph.D. [transcript]. October 17.

Zoch, R. 2020. Expert Report of Robert M. Zoch, Jr., PE in the Matter of Pamela Butler, et al. v. Mallinckrodt LLC and Cotter Corporation (N.S.L.). March.

EXHIBIT A
CURRICULUM VITAE

RAMBOLL

ENVIRONMENT & HEALTH

DOUGLAS D DAUGHERTY

Western Region COO
Director of Strategy, Americas

Dr. Douglas Daugherty has over 20 years of experience using his cross-disciplinary background in chemical engineering and industrial hygiene to provide solid solutions in areas such as industrial hygiene, air quality, air toxics risk assessments, emergency release, indoor environmental quality and litigation support. He specializes in analyzing the impacts of air emissions and emergency releases from industrial facilities. This includes emission estimations using his chemical engineering background, dispersion modeling of both buoyant and dense gases, and the assessment of impacts of explosions and fires resulting from releases of flammable substances. Doug has also prepared and evaluated numerous California Environmental Quality Act (CEQA) climate change/GHG emissions, air quality and health risk assessment analyses for port sources and other projects. He has broad experience advising and assisting facilities in a wide variety of industries with air compliance programs (both federal and state), applying exposure and health risk assessments, and providing strategic support to litigation teams.

CONTACT INFORMATION

Douglas D Daugherty

ddaugherty@ramboll.com
+1 (415) 7961932

Ramboll
201 California Street
Suite 1200
San Francisco, 94111
United States of America

EDUCATION

PhD, Chemical Engineering, Princeton University, 1994
MA, Chemical Engineering, Princeton University, 1991
BS, Chemical Engineering, Johns Hopkins University (Honors), 1989

EXPERIENCE HIGHLIGHTS

- Provided litigation support for a case involving alleged occupational exposures to diesel exhaust from mobile sources.
- In a land use permitting case, provided expert testimony regarding emergency releases from industrial facilities and their impacts to a nearby proposed development site.
- Provided litigation support and expert testimony regarding airborne emissions from industrial facilities.
- Provided litigation support and expert testimony for cases involving the historic reconstruction and/or assessment of potential occupational and public exposures.
- Provided litigation support related to a fire incident at a produced water disposal facility.
- Provided litigation support in a case involving alleged odors from a material recovery facility for commercial and municipal wastes.
- Provided litigation support in a case involving an emergency release of an odorous petroleum mixture. Estimated the

potential impact of the release using air dispersion modeling (Gaussian puff model) and fenceline monitoring data.

- Provided litigation support on mold, water damage, and/or indoor air quality (IAQ) issues to counsel for several different cases involving both housing and commercial structures in the Bay Area, Las Vegas, Nevada, Phoenix, Arizona, and Honolulu, Hawaii.
- Provided litigation support to the Santa Monica Unified School District (SMMUSD) in a Toxic Substance Control Act (TSCA) case involving polychlorinated biphenyls (PCBs) allegedly present in buildings at Malibu High School.
- Provided expert testimony services to Los Angeles Department of Water and Power in a case involving alleged underground PCB transport through conduits during a transformer fire in an underground vault in Los Angeles.
- Provided technical support and testified in a variance request application before the Bay Area Air Quality Management District (BAAQMD) for excavation and fill activities of soils containing volatile organic compounds at a brownfield redevelopment site. Work included estimating emissions and performing a population exposure assessment to determine compliance with BAAQMD regulations.
- Assessed the impact of potential accident scenarios (such as fires, explosions, BLEVEs, and toxic releases) in support of Risk Management Program (RMP)/California Accidental Release Prevention (CalARP) Program consequence analyses, CEQA determinations, and health risk assessments performed for Resource Conservation and Recovery Act (RCRA) part B permitting purposes.
- Managed accidental release impact analyses in support of local permitting requirements in several Bay Area cities. These local requirements focused on the location of sensitive receptors near industrial/commercial locations with potential toxic and/or flammable gas storage. Potential accident scenarios such as fires, explosions, and toxic releases and their potential impacts to defined endpoints were assessed as appropriate.
- Assisted a hydrogen plant facility in California with compliance with federal, state, and local regulations regarding accidental release of hazardous substances. Efforts include preparing the federal Risk Management Plan (RMP) and the California Accidental Release Prevention Program (CalARP) RMP documents in addition to performing offsite consequence analyses for regulated chemicals.
- Prepared a Risk Management Plan under the California Accidental Release and Prevention (CalARP) Program for a variety of operations. As part of services provided in support of some of these efforts, Ramboll conducted a Hazard and Operability (HAZOP) review of the current operations and made recommendations of process/operational changes to enhance the facility's accident prevention goals.
- Estimated the off-site impacts, event probability and failure frequency as part of quantitative risk analysis for a large chemical company. The event probability calculation included estimation of human error probabilities and event frequency analysis. The failure rates were estimated using the available databases on failure rates. The consequence analysis was performed using the ALOHA emergency release model. The acutely hazardous materials considered in the study were chlorine and ammonia in approximately 15 scenarios for five sites.
- Estimated the dispersion of a heavy gas released during accidental spills using several models (HEGADIS, DEGADIS, SLAB). Compared and contrasted advantages and drawbacks of each model.
- For a steel casting facility in the Bay Area, managed the development of an emission inventory, air dispersion analysis, and human health risk assessment for Air Toxics Hot Spots Information and Assessment Act (AB 2588) purposes in accordance with Bay Area Air Quality Management District (BAAQMD) and state guidelines. It was the first AB 2588 risk assessment conducted in the BAAQMD with the EPA-approved AERMOD air dispersion model.
- Conducted a screening health risk assessment to evaluate potential off-site impacts due to incremental diesel particulate emissions from the Oakland Army Base area redevelopment program. Worked with the City and Port to determine the source descriptions, including size of source (length, width, and height), location and periodicity of source emissions (time of day). Using the USEPA-approved Industrial Source Complex (ISC) model, evaluated the dispersion of

incremental diesel emissions from trucks, locomotives, and ships and the estimated incremental risks to surrounding populations.

- Assisted in the development and preparation of a second Supplemental Environmental Impact Report (SEIR) to the Final EIR for the Airport Development Program (ADP) for Oakland International Airport. Provided technical and strategic consulting assistance to the Port in support of their preparation of an airport human health risk assessment (HHRA) as a part of the second SEIR. Such assistance involved a range of technical analyses, interactions with relevant regulatory agencies (Federal Aviation Administration, U.S. Environmental Protection Agency, California Air Resources Board, and Bay Area Air Quality Management District), and strategic consultation with the Port on a range of matters related to the HHRA.
- Managed an air toxics human health risk assessment analysis for a proposed rail yard operation at the Port of Los Angeles for California Environmental Quality Act (CEQA) purposes. All potential mobile source emission sources were identified, source emission rates were calculated, and the off-site impacts were estimated using an EPA-approved Gaussian plume dispersion model (AERMOD) and standard human health assessment methodologies for cancer and noncancer effects.
- Retained by the City of Richmond as co-lead on the preparation of an Environmental Impact Report (EIR) required under the California Environmental Quality Act (CEQA) for the Chevron Richmond Refinery's Revised Renewal Project. The EIR addressed various potential environmental impacts from the Revised Project including to air quality, human health risks, greenhouse gases (GHGs), and public safety. Both changes in operations and transportation (truck, rail, and ship) were evaluated.
- Estimated the human health risks due to expected laboratory emissions from a proposed chemistry building at a California university for CEQA purposes and to assess the applicability of local air toxics regulations. This work included the performance of screening steps to reduce the number of chemicals of potential concern into a manageable number, surveying laboratory personnel to determine how these chemicals were used, development of methodologies to estimate emissions from these laboratory practices, and the estimation of off-site impact using an EPA-approved screening Gaussian plume dispersion model (SCREEN3).
- Managed dozens of air toxics human health risk assessment evaluations of emissions from a variety of industrial facilities in California for CEQA, regulatory compliance, and California Proposition 65 purposes. All potential air toxics emission sources were identified, source emission rates were calculated, and the off-site impact was estimated using air dispersion modeling and standard human health assessment methodologies for cancer and noncancer effects.
- Managed an air dispersion analysis of baseline and future-year emissions (over a 30-year expansion plan) from a mining facility in Southern California in support of a Human Health and Ecological Risk Assessment (HHERA) prepared as part of the local permitting requirements under the CEQA. Baseline and future-year concentrations were determined using an EPA-approved Gaussian plume dispersion model (ISCST3) and emissions inventories developed for baseline and future mine operation scenarios.
- Modeled the dispersion of VOC emissions from a marine tanker loading terminal using the Offshore and Coastal Dispersion Model (OCD) to estimate potential health risks to coastal residents.
- Managed the development of an Emission Inventory Plan (EIP) and Emission Inventory Report (EIR) for a mining facility in Southern California in support of reporting requirements under local district rules (MDAQMD). The development of the emission inventory required the estimation of criteria pollutant and air toxics emissions from process facilities, fugitive dust sources, and mobile source activities at the mine site. The results of the EIR were summarized as inputs into the State of California's Hotspots Analysis and Reporting Program (HARP) model for submission to MDAQMD.
- Prepared a permit application for a proposed ethanol transload facility in the Bay Area. The work included estimating emissions and public health risk impacts from the proposed operations. The facility obtained its permit from the local air district and is currently operating.
- Prepared a dust control plan for a proposed tailings pond at a mining facility in Southern California. In this plan, the emission reduction effectiveness of potential dust control measures that are

applicable to operations at the proposed facility over the next 30 years were analyzed. As part of the plan, the cost effectiveness of these dust control measures was also evaluated.

- Developed a supplemental environmental project to reduce fugitive dust emissions at a large steel facility. This involved determining the feasibility of installing dust control measures and estimating reduction in fugitive dust emissions.
- Provided air permitting services for a variety of different industries and sectors such as preparing Clean Air Act Title V permit applications and permit to install applications. Conducted regulatory rule review for assessing applicability in several California air districts including BAAQMD, SCAQMD, YSAQMD, and MDAQMD.
- Conducted several Prevention of Significant Deterioration (PSD) applicability analyses for facilities contemplating both physical and operational changes. These analyses were conducted for facilities planning expansions and for due diligence purposes.
- Worked with a major oil refinery facility to identify potential PSD-triggering equipment and operational changes and assisted the facility in addressing potential past permitting issues and in planning current permitting strategies. Also conducted a PSD significance analysis of facility emissions using an EPA-approved Gaussian plume dispersion model (ISCST3) to assist in addressing these issues.
- Conducted analyses to determine Best Available Control Technology (BACT) options for particulate, SO2, and NOx emissions from various process units at a major oil refinery facility.
- Assessed the applicability of California Proposition 65 and AB2588 regulations to a mining operation. All potential stack and fugitive emission sources were identified, source emission rates were calculated, and the off-site impact was estimated using an EPA-approved Gaussian plume dispersion model (ISCST3).
- Provided greenhouse gas (GHG) verification services to general stationary combustion sources, cogeneration plants, waste water treatment plants, and electricity generators and marketers under California rules.
- Assisted a variety of different facilities with advice on or the development of GHG Inventory Management Plans and GHG inventories for compliance under California and Federal GHG mandatory reporting rules.
- Oversaw the preparation of air quality and greenhouse gas technical reports and resource area chapters for an Environmental Impact Report (EIR) evaluating the impact of a state-wide pest eradication program. Utilizing a variety of air modeling techniques, the amount of treatment material (active ingredients and toxics) that exists in the ambient air and that deposits to the ground for each program alternative was determined. This includes drift from all application methods with special attention paid to aerial spraying. The emissions of criteria pollutants (e.g., particulates, carbon monoxide and nitrogen oxides) due to the methods of application and combustion of fuels were calculated to determine if they would result in significant impacts to the environment. The Program's impact on GHG emissions and climate change from various aspects of the program (i.e., mobile sources, portable off-road equipment) was also assessed.
- Provided GHG management-related consulting services with respect to California's Assembly Bill 32 (AB32 or the "California Global Warming Solutions Act of 2006") and USEPA's GHG MRR to a variety of industrial firms and to the Port of San Diego.
- Managed the preparation of a white paper on the potential effects of AB32 on a mining facility, which contained information on the relevant reporting standards and protocols. As part of the development of this strategic white paper analysis, baseline, current year, and 2020 projected GHG emissions for both direct and indirect sources at the facility we developed using accepted protocols. Sources at the facility included both stationary combustion and mobile sources.
- Managed the development of GHG, criteria pollutant, and/or air toxic emission inventories of mobile and stationary sources for a wide range of industry types and major transportation/goods movement facilities/operations.

- Oversaw preparation of climate change technical reports for Environmental Impact Reports (EIRs) for mixed use developments. This included developing GHG inventories for all aspects of the development (i.e., construction, energy use of buildings, mobile sources, vegetation change, and municipal sources); summarizing the current state of science and regulatory setting; presenting mitigation options; and evaluating the significance of development emissions.
- Assisted the Port of San Diego in a variety of efforts under its Sustainability and Green Port Programs. Support has included the performance of a needs assessment of the Port's existing environmental (water, energy, air (including GHG), waste management, sustainable development, and sustainable business practices) data tracking sets, their relationship to the goals and needs of the Green Port Program, and how these data sets could be integrated into a Data Management System to allow for more efficient tracking of goals under the Green Port Program.
- Worked with the Bay Planning Coalition, the Bay Area Air Quality Management District, and the 5 public Bay Area ports to develop a Bay Area Seaport emissions inventory for water and shore-based equipment and vehicles at the Ports of San Francisco, Redwood City, Richmond and Benicia.
- Oversaw the development of maritime emission inventory updates for the Ports of San Diego and San Francisco and the greenhouse gas inventories for Ports of San Diego and Portland.
- Assisted the Port of San Diego with climate mitigation and adaptation planning development, including important tools for future planning and development of Tidelands under their jurisdiction, to help the port identify, assess and develop future strategies that will help reduce GHG emissions and address local vulnerabilities to climate change. The planning also focused on regional adaptation strategies pertaining to sea level rise, water reuse and efficiency and beach erosion, as well as energy demand issues.
- Led the effort that assisted the Port of San Diego in the development of its Clean Air Program (CAP). The CAP establishes the framework for evaluating local control measures that could potentially be implemented at the port earlier or further than regulatory requirements. The CAP also identifies candidate local control measures that can be further developed into adoptable measures. As part of the CAP development, assistance was provided to the Port in presenting information and soliciting feedback from a stakeholder work group.
- Aided the Port of San Diego in the preparation of a greenhouse gas (GHG) Inventory Management Plan for Port-owned sources and their inventory for reporting under The Climate Registry (TCR).
- Managed an exposure assessment for use in an air toxics human health risk assessment analysis for all diesel-powered mobile source activities at the Ports of Los Angeles and Long Beach as part of the implementation of the San Pedro Bay Ports Clean Air Action Plan (CAAP). All potential mobile source emission sources were identified using emission rate information provided by the Ports and the off-site impacts were estimated using an EPA-approved Gaussian plume dispersion model (AERMOD) and standard human health assessment methodologies for cancer effects.
- Managed air dispersion modeling evaluations of diesel and non-diesel emissions from mobile source activities at eight BNSF rail yards in California as part of the Memorandum of Understanding (MOU) agreement between BNSF and the California Air Resources Board (CARB). All potential mobile and stationary source emission sources were identified, source emission rates were calculated, and the off-site impact was estimated using an EPA-approved Gaussian plume dispersion model (AERMOD).
- Since 2014, providing on-going support to Santa Monica Unified School District (SMMUSD) on their program to manage and replace building materials that could potentially contain PCBs based on their installation date in all the District schools built prior to 1980.
- Provided senior technical advice on remedial and exposure considerations for projects involving commercial and non-commercial buildings with PCBs in building materials.
- Managed indoor air quality (IAQ) evaluations for US Green Building Council's Leadership in Energy and Environmental Design (LEED) IAQ credit purposes. Collected wide range of samples required under LEED, analyzed laboratory reports, and summarized findings.
- Managed and performed indoor environmental quality (IEQ) evaluations for potential biological and chemical contamination in commercial and residential buildings. Collected wide range of samples, analyzed laboratory reports, and summarized findings and recommendations.

- Provided indoor air quality services to evaluate the presence of mold and volatile organic compounds (VOCs) in an office space occupied by a California state agency in Sacramento. Participated in meetings with agency staff to discuss the results of the indoor air samples, which did not indicate any significant presence of mold or VOCs. Several worker compensation claims previously filed by agency workers were denied by the State based on the results of the analysis.
- Managed an evaluation of the air filtering system used in a large commercial building. Compared the efficacy of different air filters by measuring and analyzing various parameters—including ozone, PM2.5, VOCs, aldehydes/ketones, diesel exhaust particulate matter, carbon dioxide, wind speed, pressure drop, relative humidity, and temperature.
- Evaluated the potential for vapor intrusion and/or off-gassing of VOCs from interior furnishings in several commercial buildings located near a contaminated groundwater plume in Mountain View, California. Collected air samples, evaluated sampling results, and provided recommendations for reducing potential exposures.
- Developed a sampling protocol for the first phase of a long-term monitoring program that has been successfully implemented at a mining facility in Southern California. The protocol provided details on the meteorological and ambient air sampling for compounds that may be emitted from the Facility. The constituents to be analyzed include metals, diesel, PM10, and radionuclides. This plan incorporated the following elements: program description, selection of chemicals to be sampled, selection of monitoring locations and equipment, sampling procedures and field QA/QC, laboratory analysis and laboratory QA/QC, data quality objectives, and data reporting.
- Directed and supervised interior and exterior remediation activities at commercial and residential buildings contaminated with mold and/or bacteria. This involved developing remediation protocols in accordance with applicable guidelines and overseeing the efficient implementation of site clean-ups.
- Assisted in the development of standardized methodologies for mold investigations, remediation protocols, and clearance sampling for a nationwide property management company. Also provided senior-level review of biological and chemical IEQ efforts conducted in their buildings located across the US.
- For a major insurance carrier, performed indoor air, surface, and bulk sampling for potential biological contamination in several residential dwellings in California. Remediation steps were recommended, and a list of possible contractors was identified to assist the insurance carrier with remediation efforts, if areas of concern were identified by the investigation.
- Provided strategic advice on sampling and analysis methods to evaluate the presence of airborne carbon nanotubes (CNT) from process emissions at a research operation of a large advanced technology company.
- Served as a selected panel member to discuss potential environmental concerns regarding the release of nanoparticles for a special session on nanotechnology at the American Forest and Paper Association (AFPA).
- Assessed the applicability of Occupational Safety and Health Administration (OSHA) and California Division of Occupational Safety and Health (Cal/OSHA) requirements and potential exposure limits associated with a diesel particulate filter cleaner.
- Managed the update of a safety review of low-probability, high consequence occurrences at a Department of Energy (DOE) research laboratory.
- Assisted in the development of a corporate best practices policy for the use and handling of nanomaterials and nanoparticle containing materials that was implemented across the firm's multiple business units.
- Managed the development of health and safety program elements for a leading internet company in the Bay Area with operations in several different states.
- Managed an environmental, health, and safety compliance audit of a consumer pesticide manufacturing operation and lead a team to address compliance deficiencies.

Prior to joining Ramboll (previously ENVIRON), Douglas held the following positions:

- Post-doctoral Research Engineer, Environmental Services Group, Cytec Industries, Linden, New Jersey
  - Researched bacterial populations in a novel biodegradation reactor system. Analyzed the applicability of a variety of remediation technologies (solidification, air stripping, GAC capture, trickling bed bioreactors) for company-contaminated sites from waste lagoons to contaminated ground water.
- Research Assistant, Dr. Steven Karel, Assistant Professor, Princeton University
  - Researched enhanced biodegradation of chlorinated aromatic compounds by the addition of a secondary substrate to a pump-and-treat system. Developed a model characterizing the process of dual substrate biodegradation with the accumulation of a toxic intermediate. Developed methods for toxicity studies in a 96-well plate reader.

CREDENTIALS

Registrations and Certifications

Registered Professional Engineer (Chemical), California

Certified Industrial Hygienist by American Board of Industrial Hygiene, #8481

California Air Resources Board-Accredited greenhouse gas (GHG) Lead Verifier and Transactions, Oil & Gas, Process Specialist (H-18-033)

Professional Affiliations and Activities

Member, American Institute of Chemical Engineers

Member, American Industrial Hygiene Association

Member, Air & Waste Management Association

Awards

Maryland Distinguished Scholar, 1985-1989

PUBLICATIONS & PRESENTATIONS

Daugherty, D. (workgroup chair), et al. 2019. PIANC EnviCom WG Report No 188-2019. Carbon Management for Port and Navigation Infrastructure. PIANC Secretariat General. May.

Daugherty, D. 2018. PIANC Workgroup 188 Update on Carbon Management for Port and Navigation Infrastructure at PIANC 34th World Congress. Panama City, Panama. May.

Daugherty, D. 2017. PIANC Workgroup 188 Update on Carbon Management for Port and Navigation Infrastructure at SmartRivers 2017 Conference. Pittsburgh, PA. September.

Bowie T., R. Herrmann, Y. Tian, E. Miesner, and D. Daugherty. 2017. Evaluation of PCBs in the Indoor Environment at Two Schools in Southern California. Accepted for Presentation at AIHce 2017. Seattle, WA. June.

Daugherty D., G. Greene, G. Reub, F. Kristanovich, D. Moore. 2016. Vulnerabilities to Climate Change is Not Just for Seaports – Inland River Ports Should Also Proactively Address Climate Change Vulnerabilities in their Planning Processes. IX International Conference on Coastal and Port Engineering in Developing Countries, Rio de Janeiro, Brazil. Oct.

Daugherty, D., J. Stein, C. Upton. 2016. PCBasics: PCB Management in School Facilities. Coalition for Adequate School Housing Annual Conference. Sacramento, CA. February.

Honan, S. and D. Daugherty. 2015. *Molycorp's Project Phoenix—Water and Reagent Recycling with Clean Power*, Chapter in *Responsible Mining: Case Studies in Managing Social & Environmental Risks in the Developed World*, Society for Mining, Metallurgy and Exploration (SME), January.

Lindhjem, C., T. Shah, L. Chan, T. Sturtz, D. Kim, D. Daugherty. 2014. Port Air Emissions and Vessel Speed Reduction Program Evaluation. 33rd PIANC World Congress, San Francisco, CA, June.

Daugherty, D., G. Greene, G. Reub, D. Moore. 2014. Mitigating the Risks: How Ports Can Proactively Address Climate Change Vulnerabilities in their Planning Processes. 33rd PIANC World Congress, San Francisco, CA, June.

Daugherty, D. 2013. Environmental Management Initiatives and Tools to Track Benefits—Examples from Various US Ports. 9th Ports and Terminal Technology Conference, Amsterdam, the Netherlands, November.

Hooven, C., L. Moran, D. Kim, and D. Daugherty. 2013. Local Planning for climate change within regional efforts: a case study at the Port of San Diego. 5th International Seminar of Ports and the Environment, Amsterdam, the Netherlands, November.

Hooven, C., L. Moran, D. Kim, and D. Daugherty. 2013. Port of San Diego Climate Mitigation and Adaptation Plan (Climate Plan) and the Road Ahead. Air & Waste Management Association's Meeting on Climate Change: Impacts, Policy, and Regulation, Herndon, VA. September.

Hall, L. and D. Daugherty. 2013. Are Current Strategies Sufficient to Determine Funding Allocation for California's Cap and Trade Proceeds? Air & Waste Management Association's Meeting on Climate Change: Impacts, Policy, and Regulation, Herndon, VA. September.

Kim, D., J. Forde, and D. Daugherty. 2013. Complexities in Defining Boundaries for Mandatory Greenhouse Gas Reporting. Air & Waste Management Association's Meeting on Climate Change: Impacts, Policy, and Regulation, Herndon, VA. September.

Chan, L. and D. Daugherty. 2013. US Port Air Quality Initiatives: Opportunities for China. China Green Port Technologies Reverse Trade Mission sponsored by US Trade and Development Agency, Long Beach, CA. July.

Daugherty, D. D. and K. Poloncarz. 2012. Effect of Emerging GHG Laws on Major Stationary Sources. CLE International Conference on Greenhouse Gas Emissions, San Francisco. July.

Hooven, C., J. Hirsch, M. White, S. Messner, D. Kim, L. Moran, and D. Daugherty. 2011. San Diego Unified Port District Climate Mitigation and Adaptation Plan (CMAP). Air & Waste Management Association's Meeting on Greenhouse Gas Strategies in A Changing Climate, San Francisco, CA. November.

Harper, P., M. Posson, and D. Daugherty. 2011. Non-traditional Land Uses and Emergency Planning: Challenges Associated with Developing Plans to Mitigate Impacts from Potential Toxic Gas Releases. Presented at AIHce 2011, Portland, Oregon. May.

Daugherty, D.D. 2010. Invited Panel Member: "Economic Recovery, Infrastructure Funding, and Air Quality: Progress or Impasse?", Bay Planning Coalition Workshop, Oakland, CA. September

Daugherty, D.D. 2010. Moderator for Carbon Management Panel: Regulations and Emerging Policies. Climate 3.0, 23rd Annual San Francisco Bay Decisionmakers Conference. April.

Daugherty, D. D. and K. Shea. 2009. Greenhouse Gas Reporting Rule Overview. Power Magazine Webinar. December.

Daugherty, D. D., S. Ramsey, and C. Colville. 2009. Greenhouse Gas Reporting Rule Workshop. ENVIRON, Houston, TX. November.

Daugherty, D. D. 2009. EPA Mandatory Reporting of Greenhouse Gases Rule. Law Seminars International Telebriefing. October.

Daugherty, D. D., M. Keinath, and M. Posson. 2009. A Case Study in Avoiding Pitfalls of Conducting LEED IAQ Testing. Presented at AIHce 2009, Toronto, Canada. June.

Li, W., D. D. Daugherty, and E. Liu. 2009. Evaluation of IEQ for Office Spaces in China Against TVOC Standards. Presented at AIHce 2009, Toronto, Canada. June.

Payer, B. W., S. Lee, G. M. Hoch, and D. D. Daugherty. 2008. Evaluation of Source Selection and Representation for Mobile Emission Source Activities on Air Dispersion Modeling Setup Time, Run

Time, and Modeling Results Using AERMOD. Presented at 2008 Annual Meeting, Air & Waste Management Association, Portland, Oregon. June.

Daugherty, D.D. 2008. Introduction to AERMOD Dispersion Modeling. A one and half day course presented in Sydney Australia. May.

Daugherty, D.D. 2008. West Coast Ports Emission Reduction Initiatives. Bay Planning Coalition's 25th Anniversary Decision-makers Conference. April.

Payer, B. W., S. Lee, G. M. Hoch, and D. D. Daugherty. 2008. Assessing the Uncertainty from Source Selection and Representation for Mobile Emission Source Activities in Air Dispersion Modeling Assessment of Goods Movement Facilities. Poster presented at Transportation Research Board of the National Academies Data for Goods Movement Impacts on Air Quality Conference, Irvine. March.

White. M., D. Merk, L. Bentley, J. Lester, and D. D. Daugherty. 2008. Development of a Voluntary Clean Air Program at the Port of San Diego. Poster presented at Transportation Research Board of the National Academies Data for Goods Movement Impacts on Air Quality Conference, Irvine. March.

Daugherty, D. D. and K. Poloncarz. 2008. Going "Carbon Neutral", Legal and Technical Issues Associated with Quantifying, Mitigating, and Offsetting Climate Change Impact. CLE International Green Building Conference, San Francisco. February.

Daugherty, D.D. 2007. Carbon Management – A Case Study Using ENVIRON's Six-Step Plan. Part of ENVIRON seminars, "Optimizing Your Strategic Response to Upcoming Carbon Management Regulations" and "Optimizing Your Strategic Response to AB 32, California's Carbon Management Requirements: Lessons Learned from the EU Experience". October 25 in New York City, January 24 in San Francisco, and January 25 in Los Angeles

Mukai, C., T. Bowie, G. Hoch, and D. Daugherty. 2007. Evaluation of Urban Boundary Layer Parameters in AERMOD or Poorly-Defined Urban Areas. 2007 Annual AWMA Meeting. Pittsburgh, PA. June.

Bentley, L., T. Bowie, G. Hoch, and D. Daugherty. 2007. Specification of Surface Parameter Values for the AERMET Preprocessor for Geographical Areas with Atypical Seasonal Patterns. 2007 Annual AWMA Meeting. Pittsburgh, PA. June.

Daugherty, D.D., D. J. Mundt, K. A. Mundt, R. C. Adams, and A. Santamaria. 2006. A Best Management Practices Approach to Nanoscale Materials and Occupational Health Concerns. 2006 Annual American Institute of Chemical Engineers Meeting. San Francisco, CA. November.

Daugherty, D.D., D. J. Mundt, K. A. Mundt, R. C. Adams, and A. Santamaria. 2006. Guarding the Promise: Managing the Environmental and Occupational Health Uncertainties of Nanotechnology Today. International Conference on Nanotechnology (ICNT) 2006. South San Francisco, CA. November.

Hoch, G., C. Barney, and D. D. Daugherty. 2006. A Case Study In Meteorological Monitoring: Evaluation Of Potential Impacts On Data Quality Using Non-Traditional Data Analysis Techniques. Paper 495. 2006 Annual Meeting, Air & Waste Management Association, New Orleans, LA. June.

Daugherty, D. D. 2006. Nanoproducts – Environmental Fate and Transport. Invited Speaker of Panel Session on Nanotechnology at American Forest and Paper Association meeting. May.

Bowie, T., M. T. Keinath, E. Miesner, C. Stubbs, and D. D. Daugherty. 2006. Validation of the Johnson and Ettinger Vapor Intrusion Model Applied to Commercial Buildings. Presented at AIHce 2006, Chicago, IL. May.

Daugherty, D. D. 2006. Health and Environmental Concerns of Nanotechnology for the Building Industry. Presented at Safety & Health Council, Associated General Contractors of California. April.

Mundt, D. J., K. A. Mundt, A. Santamaria, and D. D. Daugherty. 2006. Regulatory Dimensions of Nanotechnology. Presented at Shook, Hardy and Bacon, Kansas City, MO. February.

Mundt, D. J., K. A. Mundt, R. C. Adams, A. Santamaria, and D. D. Daugherty. 2005. Pragmatic Approaches to Managing Occupational Health Uncertainty. Presented at 2nd International Symposium on Nanotechnology and Occupational Health, Minneapolis, MN. October.

Daugherty, D.D., T. Bowie, G. Hoch, and E. Lu. 2004. Importance of Characterizing Sampling Variation in Fungal Sampling Studies Utilizing Small Sample Numbers. Presented at AIHce 2004, Atlanta, GA. May.

Daugherty, D. D., K. Mertz, and G. Caviness. 2004. Case Study Of A Potency-Weighted Emission Screen. Environmental Progress, Vol. 23(2): pp. 168-177.

Daugherty, D. D. 2003. Mold – A Successful Approach for Property Buyers and Owners/Sellers (Invited). Presented to Wells Fargo Home Mortgage and Chicago Title Company, San Francisco, CA. July

Daugherty, D. D., W. Li, K. Mertz, and S. Hayes. 2003. The Importance of Surface Roughness Selection in AERMOD Modeling for Shoreline Sources. Paper 81161. 2003 Annual Meeting, Air & Waste Management Association, San Diego, CA. June.

Daugherty, D. D., K. Mertz, and G. Caviness. 2003. Case Study Of A Potency-Weighted Emission Screen. Paper 19c. Presented at 2003 AIChE Spring National Meeting, New Orleans, LA. April.

Daugherty, D. D. 2003. Mold – A Successful Approach for Property Buyers and Owners (Invited). Presented at the Real Estate Round Table, San Francisco, CA. January.

Daugherty, D. D. 2002. Special Session on Mold. Presented and Chaired at Air & Waste Management Association Special Symposium on Air Quality Measurement Methods and Technology, San Francisco, CA. November.

Daugherty, D. D. 2002. Mold and Due Diligence. Presented at Environmental Bankers Association Meeting (Invited). St. Paul, MN. June.

Daugherty, D. D., K. Mertz, and G. Caviness. 2002. Case Study Of A Potency-Weighted Emission Screen: Initial Evaluation. Paper 42728. Presented at 95th Annual Meeting, Air & Waste Management Association, Baltimore, MD. June.

Daugherty, D. D. and S. Hayes. 2001. Screening-Level Risk Analyses Of Fluid Catalytic Cracking Units At Twenty-Five Refineries. Paper 504. Presented at 94th Annual Meeting, Air & Waste Management Association, Orlando, Florida. June.

Daugherty, D. D. 2001. Mold – The Initial Investigation. Invited lecture at Golden Eagle Insurance, San Diego, California, and Highlands Insurance Group, Los Angeles, California. January.

Daugherty, D. D. 2000. Mold and Construction Defects. Invited lecture at Bishop, Barry, Howe, Haney & Ryder Annual Silverado Symposium, Silverado, California. May.

Daugherty, D. D. and S. F. Karel. 1994. Degradation of 2,4-Dichlorophenoxyacetic Acid by Pseudomonas cepacia DBO1(pRO101) in a Dual Substrate Chemostat. Applied Environmental Microbiology, 60:3261-3267.

Daugherty, D. D. 1994. Degradation of 2,4-Dichlorophenoxyacetic Acid by Pseudomonas cepacia DBO1(pRO101) in Mixed Substrate Systems. Doctoral dissertation, Princeton University, Princeton, New Jersey. November.

Daugherty, D. D. 1993. Degradation of Chloroaromatic Compounds in the Presence of Additional Substrates by a Model Bacterial System. Seminar presented at Princeton University, Princeton, New Jersey. May.

Daugherty, D. D. 1992. Degradation of 2,4-Dichlorophenoxyacetic Acid in the Presence of Succinate by Pseudomonas cepacia DBO1(pRO101). Presented at AIChE Annual Meeting, Miami Beach, Florida. November.

Daugherty, D. D. 1992. Initial Results of 2,4-Dichlorophenoxyacetic Acid Degradation in the Presence of Succinate by Pseudomonas cepacia DBO1(pRO101). Presented at MABEC Annual Meeting, Rutgers, the State University of New Jersey, New Brunswick, New Jersey. March.

EXHIBIT B
LIST OF EXPERT TESTIMONY SINCE 2015

DEPOSITION AND COURT TESTIMONY
Douglas D. Daugherty, PhD, PE, CIH

In the past 5 years, Dr. Daugherty has been deposed and given trial or hearing testimony in the following cases:

1. Don Strong, et al. vs. Republic Services, Inc., et al.; Case No. 17SL-CC01632-01 and Bridgeton Landfill, LLC v. Cotter Corporation (N.S.L); Case No. 17SL-CC01632-02, In the Circuit Court of St. Louis County, State of Missouri

   - Deposition (January 15, 2020)

2. Laurie Freeman, Joseph Preston et al. vs. Grain Processing Corporation; Case No. LACV021232, In the Iowa District Court for Muscatine County

   - Deposition (April 29-30 & May 1, 2018)

3. America Unites for Kids, et al. vs. Sandra Lyon, et al.; Case No. 2:15-CV-02124, In United States District Court for Central District of California, Western Division

   - Written Trial Testimony (April 25, 2016)

4. Laurie Freeman, et al. vs. Grain Processing Corporation; Case No. KACV921232, In the Iowa District Court for Muscatine County

   - Deposition (March 26-27, 2015)

EXHIBIT C
LIST OF OTHER MATERIALS REVIEWED

Clark, J. 2019. Deposition of James J.J. Clark, PhD in the Matter of Pamela Butler v. Mallinckrodt, LLC & Cotter Corp. and Exhibits. September 18.

Clark, J. 2019. Exposure Analysis for Anthony Hines in the Matter of Anthony Hines v. Mallinckrodt, LLC & Cotter Corp. March 31.

Clark, J. 2019. Exposure Analysis for Emery David Walick, II in the Matter of Emery David Walick, II v. Mallinckrodt, LLC & Cotter Corp. March 31.

Clark, J. 2019. Exposure Analysis for Kenneth Korterba in the Matter of Kenneth Korterba v. Mallinckrodt, LLC & Cotter Corp. March 31.

Clark, J. 2019. Exposure Analysis for Pamela Butler in the Matter of Pamela Butler v. Mallinckrodt, LLC & Cotter Corp. March 31.

Clark, J. 2019. Supplemental Exposure Analysis for Emery David Walick, II in the Matter of Emery David Walick, II v. Mallinckrodt, LLC & Cotter Corp. September 4.

Hu, Howard. 2019. Deposition of Howard Hu, MD, MPH in the Matter of Pamela Butler v. Mallinckrodt, LLC & Cotter Corp. and Exhibits. October 9.

Hu, Howard. 2019. Expert Report for Anthony Hines in the Matter of Anthony Hines v. Mallinckrodt, LLC & Cotter Corp. April 1.

Hu, Howard. 2019. Expert Report for Emery Walick in the Matter of Emery David Walick, II v. Mallinckrodt, LLC & Cotter Corp. April 1.

Hu, Howard. 2019. Expert Report for Kenneth Korterba in the Matter of Kenneth Koterba v. Mallinckrodt, LLC & Cotter Corp. April 1.

Hu, Howard. 2019. Expert Report for Pamela Butler in the Matter of Pamela Butler v. Mallinckrodt, LLC & Cotter Corp. April 1.

United States District Court, Eastern District of Missouri, Eastern Division. Case Management Order No. 14 for Future Consolidated Cases Filed Against Cotter Corporation (N.S.L) and/or Mallinckrodt LLC. 2018. Oct. 15.

United States District Court, Eastern District of Missouri, Eastern Division. Case Management Order No. 1 Regarding Butler v. Mallinckrodt LLC, No. 4:18-CV-01701-AGF., et al. 2019. Nov. 11.

United States District Court, Eastern District of Missouri, Eastern Division. Case Management Order No. 1 Regarding Butler v. Mallinckrodt LLC, No. 4:18-CV-01701-AGF., et al. 2019. June. 19.

Wells, J. 2019. Supplemental Expert Report of James T. Wells, PhD, PG in the matter of McClurg, et al. v. Mallinckrodt, Inc., et al. August 1.

EXHIBIT D
REVISED FENCELINE RADIONUCLIDE CONCENTRATIONS

Table D1: Comparison of Dr. Wells' Predictions to Revised Fenceline Radionuclide Concentrations for Cotter's Operational Period (1970-1971)

Isotope	Dr. Wells' Annualized ($pCi\ m^{-3}$)[1]	AERSCREEN, Annualized Maximum ($pCi\ m^{-3}$)[2]	% Reduction[3]
^{238}U	0.0045	0.0024	45%
^{230}Th	0.41	0.22	45%
^{226}Ra	0.0030	0.0017	44%
^{210}Pb	0.0030	0.0017	44%
^{232}Th	0.000029	0.000016	45%
^{234}U	0.0045	0.0024	45%
^{228}Ra	0.0000082	0.0000044	46%
^{228}Th	0.000026	0.000013	48%
^{231}Pa	0.024	0.013	44%
^{227}Ac	0.024	0.013	44%

Notes

[1] Calculated from quarterly results in Table 3 of Dr. Wells' Report.

[2] Includes revisions from overstated emissions (see Table 5-1) and use of AERSCREEN.

[3] Variation in percent reduction due to rounding.

Table D2: Comparison of Dr. Wells' Revised Fenceline Radionuclide Concentrations from Latty Avenue Drying Operations to 10 CFR §20.106 Effluent Limits for Cotter's Operational Period (1970-1971)

			Soluble Fraction		Insoluble Fraction	
Isotope	**Solubility %[1]**	**AERSCREEN, Annualized Maximum ($pCi\ m^{-3}$)[2]**	**Soluble Effluent Limits ($pCi\ m^{-3}$)**	**AERSCREEN, Annualized Maximum Soluble Fraction ($pCi\ m^{-3}$)**	**Insoluble Effluent Limits ($pCi\ m^{-3}$)**	**AERSCREEN, Annualized Maximum Insoluble Fraction ($pCi\ m^{-3}$)**
^{238}U	1.3	0.0024	3	0.000032	5	0.0024
^{230}Th	<1	0.22	0.08	0.0022	0.3	0.22
^{226}Ra	0.12	0.0017	3	0.0000020	2	0.0017
^{210}Pb	_[3]	0.0017	4	0.0017	8	_[3]
^{232}Th	_[3,4]	0.000016	1	0.000016	1	_[3,4]
^{234}U	_[3]	0.0024	20	0.0024	4	_[3]
^{228}Ra	_[3]	0.0000044	2	0.0000044	1	_[3]
^{228}Th	_[3]	0.000013	0.3	0.000013	0.2	_[3]
^{231}Pa[5]	<0.1	0.013	0.04	0.000013	4	0.013
^{227}Ac[5]	<0.1	0.013	0.08	0.000013	0.9	0.013

Notes:

[1] Source: Zoch 2020, Table 4

[2] Includes revisions from overstated emissions (see Table 5-1) and use of AERSCREEN.

[3] Mr. Zoch does not provide specific solubility numbers for these radionuclides in his report. To be conservative, concentrations are compared to the lower soluble effluent limits.

[4] RAC 2018 indicates that 232-Th, 230-Th, radium as barium sulfate, and uranium are all insoluble in water.

[5] Protactinium-231 and Actinium-227 were not sufficiently soluble for detection in leachate, indicating solubilities of <0.1% (Zoch 2020).